DEDICATED

TO

LOTUS FEET

OF

MY PARENTS

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CERTIFICATE

This is to certify that Thesis work entitled **"Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice - wheat sequence"** is an original piece of research work done by **Mr. Binod Kumar Pandey** under my supervision for the degree of **Doctor of Philosophy in Agriculture (Agronomy)** of Bundelkhand University, Jhansi (U.P.).

I further certify that: -

a) The Thesis has been completed.
b) The work embodied in the thesis is of candidate himself.
c) It is an original piece of research work.
d) The Thesis fulfils the required attendance as laid down by the University.
e) It is up to standard in respect of its contents and literacy presentation for being referred to examiners.

Dated : 12-04-2010

Mata Din Lodhi

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DECLARATION

I hereby declare that the thesis entitled **"Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice – wheat sequence"** being submitted for the degree of **Doctor of Philosophy in Agriculture (Agronomy)** to the Bundelkhand University, Jhansi (U.P.) is an original piece of research work done by me and to the best of my knowledge and belief, it is not substantially the same one which had already been submitted for the degree of any other academic qualification at any other university or examining body in India or abroad.

Place: Rath
Dated 12-04-2010

(Binod Kumar Pandey)

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Place: Rath
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(Binod Kumar Pandey)

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ABBREVIATIONS

%	=	per-cent
@	=	At the rate of
°C	=	Degree Celsius (formerly degree centigrade)
Agril	=	Agricultural
Agron	=	Agronomy
Am.	=	American
CD	=	Critical Difference
Cm	=	Centimetre
d.f.	=	Degree of freedom
DAS	=	Days after sowing
dSm^{-1}	=	Die Simen per metre
et al.	=	et alii (and others)
etc.	=	et cetra
Fig.	=	Figure
Fmg.	=	Farming
G	=	Gram
ha^{-1}	=	Per hectare
i.e.	=	Idest, that is
ICAR	=	Indian Council of Agriculture Research
IARI	=	Indian Rice Research Institute Agriculture
J	=	Journal
kg	=	Kilogram
Km	=	Kilometre
L	=	Litre (s)
L	=	Lin. nae.us (Swedish botanist)
LAI	=	Leaf area index
M	=	Metre
Mm	=	Millimeter
Mt	=	Million tonne
NS	=	Non significant
Q	=	Quintal
SE	=	Standard error
SEm±	=	Standard error of mean
Viz.	=	Videlicet, namely
IRRI	=	Indian Rice Research Institute

Chapter one

INTRODUCTION

Chapter-I

INTRODUCTION

Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping system has a long history in Asia. This cropping system has been practiced in China since 700 AD, India (Uttar Pradesh) since 1872, Punjab (India and Pakistan) and in Bengal (India and Bangladesh) since 1920. Rice and wheat are currently grown in rotation on almost 26 million hectares of South and East Asia under diverse climatic and soil condition (Timsina and Connor 2001), contributing 72, 85, 92, 100 and 71% of the total cereal pool of China, India, Pakistan, Bangladesh and Nepal, respectively. Singh and Paroda, (1994); Asalam, (1998) and Yadav *et al.* (1998). Rice-wheat is the dominant cropping system of Indo-Gangetic plains of India. However major expansion of this system has taken place after the introduction of high yielding semi dwarf short duration varieties of rice and wheat. In 1960-61, this system was predominantly followed in 38 districts covering 2 to 4 million hectare area, while in 1990-91 the system expanded to occupy dominant position in 123 district covering 9.8 million hectare (Yadav and Subba Rao, 2001).

With the development of high yielding, photo-insensitive cultivars of rice and increased irrigation facilities, the rice cultivation has extended to non-traditional areas of North India where wheat was dominant crop in winter. Similar cultivation of wheat extended to

some of the traditional rice areas due to development of high yielding, semi-dwarf wheat varieties responsive to nutrient and water. This development scenario makes Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and Madhya Pradesh the heartland of rice-wheat cropping system (Gill, 1994). In U.P. 43% cropped area in *Kharif* is under rice and most of early and medium duration rice is followed by wheat in *Rabi* that making the rice-wheat system as the most important sequence in state. This can be evident from the fact that the contribution of rice-wheat in national food grain production has increased from 52% during sixties to 75% during mid nineties. Out of the total food grain production 182.57 million tonnes in 2002-03 rice contributed about 75.72 and wheat about 69.31 million tonnes (Venkataramani, 2004).

Recently it has been observed that the system is showing sign of fatigue and the crop yield is either stagnating or the factor productivity has fallen down thereby suggesting the requirement of more input to produce the same grain yield from unit area. Kulkarni *et al.* (1987) presented data from long term rice-wheat system trials at Pantnagar, which showed that wheat yield exhibited a declining trend when rotation was in vogue from 7-9 years, besides other factors, the reduction in wheat yield in rice-wheat system is due to poor soil physical condition, poor fertility status and inadequate residue, nitrogen and tillage management practices. Abrol *et al.* (1998) also stated that productivity growth of rice-wheat system has gone down and that the use of productivity enhancing inputs appears to be

approaching saturation. Declining soil fertility resulting from depletion of nutrients, their imbalance application and reduced recycling of organic matter, water-induced degradation of soil and water resources leading to spread of salinity and water balance aberrations, increase in the incidence of pest and disease and loss in biodiversity are some of the factors that adversely affect the sustainability of the production system. Long term fertilizer trials at Pantnagar conducted from 1984-1997, showed yield decline in rice-wheat cropping systen regardless of treatments (Lal, 1998).

There are substantial areas under rice which are combined harvested and also increasing tendency among the farmers to harvest the crop just near the earhead leaves behind enormous quantity of organic matter. The area being harvested with combine is increasing every year. Nearly 3/4th of the crop residue amounting a million of tonnes is disposed off by burning. The primary reason for burning rather than incorporation for enriching the soil is absence of any suitable residue management practice. The total nutrient value of residues are half of the total contents because it is known that only about 50% of the nutrients are mineralized in the soil on decomposition of crop residues. Their conservative estimates reveal that about 1.6 million tonnes of nutrients from crop residues in rice-wheat system are available for recycling. Besides NPK, the residues also contain appreciable amount of secondary and micronutrients. Based on the above assumptions, it is estimated that about 43 and 37 million tonnes of rice and wheat straw, respectively are available for

utilization from rice-wheat system in India. The total nutrient value (in terms of NPK) of these crop residues is estimated to be about 4.8 mt, which can replace about 30% of the total fertilizer consumption in the country with the intensification of agriculture especially in rice-wheat growing regions of the country.

Large amount of crop residues are available primarily due to adaptation of high yielding varieties coupled with heavy use of chemical fertilizers and assured irrigation. This intensification and maximum use of inputs will also continue in future keeping in view of the demand of extra food grain for meeting the requirement of growing population. Secondly with the introduction of mechanical harvesters, large amount of crop residue are available in rice-wheat growing areas. Part of these residues is used as animal feed as well as for various agriculture and horticultural purposes and a substantial quantity is used for various commercial purposes. Collection and disposal of residue is a practical problem where, the mechanical harvesting is practiced. Consequently, farmer prefers to burn residues in the field leading to loss of costly nutrients stored in it and also causing environmental pollution. The heat produced in burning destroys beneficial microorganisms in soils where residue is burnt repeatedly. The preliminary work carried out at PAU indicated that the wheat crop performance following rice residue incorporated and residue-burning situation tends to be alike. However, often to achieve this status, these require, gestation period of 3-4 years before equilibrium conditions set in. Besides to accelerate the decomposition

process, some time and additional application of about one third nitrogen also need to be applied at the time of incorporation along with an additional irrigation during the post harvest decomposition phase. Incorporation of residues of rice-wheat increased the productivity of the system due to increasing the organic matter (Sharma and Mitra, 1989). Rice and wheat straw are incorporated in soil before sowing of succeeding crop in rice-wheat system. The period available for decomposition of crop residue is important so as to ensure mineralization of nutrients. Decomposition of rice-wheat straw having wide C:N ratio which decomposes slowly in the soil. However, their decomposition is highly influenced by soil properties, temperature and moisture regime. During decomposition process, soil microorganisms assimilate carbon of the waste material for the production of new cells. This therefore, leads to decline in availability of plant nutrients due to immobilization. The decomposition of crop residues is a complex microbial process controlled by a number of factors. Among these, biochemical composition of residue exerts an important influence on the decomposition process (Heal *et al.*, 1997).

The significance of recycling the organic resources for replacement of plant nutrients and maintenance of soil health has already been established. However, the limited availability of organic manures and almost nil possibility of in-situ green manuring for wheat after the harvest of rice, the only alternative left is the direct incorporation as rice crop residue to maintain soil organic carbon.

A largest amount of crop residue is left after the harvest of crops which may affectively utilized as auxiliary organic matter sources. However, keeping in view the economic significance of straw as potent source of feed of cattle, the unused portion of straw and roots left, may be recycled for this purpose and would contribute substantially if the rice is harvested by mechanical harvestor which is now gaining popularity due to paucity of labour during harvesting time.

Crop residue represents an important group of organic manures. On the whole those crop residues that are unpalatable to cattle are emphasized more often others. Though the C/N ratio of these materials is very wide restricting their nutrient contribution over time, benefits from even such wide C/N ratio materials were released (Dhillon and Dev, 1984). Singh and Das (1984) established for greater advantages from crop residue where the soil organic matter level is exceptionally low. Notwithstanding the prior decomposition of organic materials is important to ensure benefit to crop with no deleterious effect such as nitrogen immobilization by microorganisms.

The information generated thus far shows that less than 10 per cent to over 50 per cent of total nutrients especially nitrogen contained in an organic material is useful for the first crop. Wide variations of this kind in nutrient supply are governed by the nature of organic content i.e. the state of decomposition and C/N ratio, because advantages from organic matter occurs only once it has decomposed. Majority of commonly use organic matter decompose slowly. Consequently nutrient sully lingers over a long time. During

the decomposition of organic materials with wider C/N ratio availability of nitrogen required for fast multiplication and activities of microorganisms responsible for decomposition becomes restricted. Under such situation addition of N in form of chemical fertilizer will accelerate the pace of liberalization of cereal residues poor in nitrogen by checking immobilization. Immobilization of N is usually associated with high C/N ratio materials and it is not observed with C/N ratio is brought down to 40 when mineralization of N is satisfactory and steady. Thus, addition of chemical N fertilizer can prove advantageous in lowering the C/N ratio of cereal crop residues. This would not only enhance the nutrient availability but coupled with product of organic matter decomposition exert a strong influence on the efficiency of fertilizer nutrients.

It thus becomes evident that genesis of beneficial transformational products linking nutrient availability with organic treatment, with supplemental nitrogen will go a long way in improving the productivity of soil on sustainability basis for longer period. Apart from this, it is well established that organic matter increase the microbiological groups of microorganism such as phosphorus mineralizers and solubilizers, in addition to reduction of N loss by microbial immobilization and retention of N in colloidal exchange complex of organic matter. Phosphate fertilizers from insoluble complexes on application to soil lowering its efficiency. Phosphate fertilizers efficiency can also be improved by incorporation of organic

matter with phosphorus fertilization. Similar information is also available with potash fertilizer with organic matter incorporation.

Generally, Indian soils are deficient in nitrogen due to adoption of multiple cropping and introduction of high yielding varieties, which exploited the high quantity of nitrogen from the soil. It is essential for carbohydrate utilization within the plants and stimulates root growth and development as well as the uptake of phosphorus and potassium of the macro-nutrients usually applied in commercial fertilizers, it seems to have the quickest and most pronounced effect and increases above ground vegetative growth and imparts deep green colour to the leaves, In wheat, it increases the plumpness of the grain and the percentage of the protein, where under insufficient supply of nitrogen plants become stunted in growth and posses restricted root growth as well as the leaves turn yellow or yellowish green and tend to drop off. For producing one tonne of grains 35-40 kg nitrogen is absorbed by the wheat crop. In rice-wheat sequence, wheat crops needs higher dose of nitrogen and management since rice stubbles cause nitrate depression period of about 4-6 weeks. Moreover, under residue management the rate of mineralization is low, therefore higher rate of nitrogen may be required. Considering the above facts and realizing the felt need to production in Bundelkhand condition, an investigation entitled **"Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice - wheat sequence"** was, therefore, undertaken for two years (2007-08 and 2008-09) at the Agriculture Research Farm of

Brahmanand Post Graduate College, Rath (Hamirpur) U.P. with a view to achieve the following contemplated objectives:

(i) To study the effect of stubble incorporation on growth and yield of wheat.

(ii) Evaluating the effect of supplementary application of fertilizers on crop residue decomposition in increasing yield in relation to recommended dose of fertilizer application.

(iii) To study the effect of residue incorporation on organic carbon status of soil.

(iv) To study the cost effectiveness of various residue managements.

(v) To calculate the cost of cultivation and net profit to various treatments.

Chapter two

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Production potential of wheat is governed by large number of climatic, edaphic and agronomic factors. No doubt, among these rice residue management and nutrient management are the most important factors. In present time large area of rice-wheat cropping system is harvested by combine harvester, which leaves, large amount of residue in the field. How this residue should be managed for increasing the soil fertility is the problem with Indian farmers. The relevant works done on different aspects in India and abroad is compiled and presented in this chapter.

2.1 Effect of residue management:

2.1.1 Growth, development, yield and yield attributes:

Griffin *et al.* (1981) conduct ed a ~~the~~ trial in SW Louisiana in 1981, wheat Cv. Coker 68-15 was cut to (a) 6 or (b) 12 inch stubble height, with subsequent spreading of straw or to 6 inch with (c) removal (d) burning or (e) incorporation of straw before sowing soybean Cv. Terra Vig 708 directly on 22 May. By late June, stubble treatment had little effect on establishment and ~~or~~ plant height.

Bali (1982) reported that application of starter dose @ 15 kg N ha^{-1} resulted in significant increase in grain and straw yields of wheat and rice in all the cropping season at Palampur. Incorporation of straw with starter dose of nitrogen (20 kg N/ ha) was found slightly

better than burning and straw incorporation without starter dose of nitrogen. Bacon *et al.* (1982) observed that stubble incorporation ~~sown~~ after rice harvested resulted in N immobilization prior to sowing with little effect on the wheat crop. While incorporation prior to ~~immediately before~~ wheat sowing lead to immobilization of N and reduced yield.

Sharma *et al.* (1985) reported that incorporation of straw of each crop after harvest improved soil properties, but had no effect on yield. Both crops name as crops showed response to increasing N rate (0-100 kg/ha). Kavimandan *et al.* (1987) observed that application of FYM + NP and rice straw + NP gave grain yield of 3.54-3.79 and 3.07-3.64 t ha^{-1} respectively, compared with 4.3 t with NPK and 2.40 t without fertilizers. Yield of rice and wheat were increased by FYM and N, while plant residue had no effect reported by Sharma et al. (1987).

Maskina *et al.* (1987) found that wheat straw incorporation and straw burning both had higher grain and straw yield of rice over the straw removed from field. Comparing the two, straw burning was better over the straw incorporation. The same finding was also reported by Sharma *et al.* (1991) and Bhagat and Verma, (1991). Srivastava *et al.* (1988) observed that the crop yield followed an increasing trend with a corresponding increase in the level of organic matter accumulation and nitrogen status. However, application of organic waste at a moderate level (2.5 t ha^{-1}) gave a good response compared with the maximum level. Sharma and Mitra, (1989) concluded that straw incorporation with starter dose of 20 kg N ha^{-1} gave higher value of yield attributes over straw incorporation only.

Bhat *et al.* (1991) reported that the dry matter yield of maize increased as a result of residue incorporation over residue removed and burnt. Azam *et al.* (1991) found that increase in 1000-grain weight of wheat due to incorporation of rice straw. Singh *et al.* (1992) reported that incorporation of rice straw three weeks before wheat sowing significantly increased wheat yield on a clay loam soil but not on a sand loam soil. Verma and Bhagat (1992) conduct the trial at Palampur and the treatment were rice straw was removed (C), chopped and incorporated (SI), Mulched (SM), burnt (SB) or incorporated with animal manure (SI+AM), or animal manure alone was incorporated (AM). Both rice straw and manure were applied at 5 t ha^{-1} (DW basis). Wheat yield was higher in AM and SM than in C and SB. Yield was low in SI + AM than in AM during the 1st crop, equal to AM and SM during the 2nd and 3rd crops and higher from the 4th crop onwards. SI gave lower yield than C in the 1st 2 crops, but similar performance to AM and SM form 4th crop onwards. Tamak *et al.* (1993) reported that the soil incorporation of rice stubble or straw + stubble had no significant effect on seedling emergence but increased grain yield plant^{-1} by 13.14 and 12.16%, respectively.

Alam *et al.* (1994) reported that incorporation of rice residue @ 5.0 t ha^{-1} along with recommended dose of NPK had increased the number of spikes per unit area, number of grains per spike, test weight and grain yield of wheat. Beneficial effect of residue incorporation on plant height, number of tillers, yield attributes and yield of rice and wheat were also recorded by Meelu *et al.* (1994).

Beri *et al.* (1995) reported that residue burning and residue removal resulted in greater grain yields of rice (5.57 and 5.53 t ha^{-1} respectively) and wheat (4.12 and 4.02 t ha^{-1}, respectively) than residue incorporation (4.51 t ha^{-1} rice and 3.72 t ha^{-1} wheat). Gupta *et al.* (1995) noted that wheat grain yield was not influenced significantly in rice residue removal, incorporation with or without starter dose of nitrogen or residue burning treatments during two year of experiment~~al~~ation at Pantnagar.

The results of field experiments at different location during 1984-85 to 1992-93 revealed that application of FYM along with rice residue incorporation had favorable effect on growth characters, yield and yield attributes of wheat (Hegde 1998). Singh *et al.* (1998) reported that growth and yield attributes of wheat increased with use of organic sources (poultry manure and crop residue) with recommended dose of NPK. Dhiman *et al.* (2000) concluded on the basis of long term experiment from Hissar, that grain yield of wheat was adversely affected by the incorporation of residue during initial year of study. However, the deleterious effect was counter balanced during the subsequence year. Wheat grain and straw yield were not affected significantly by the incorporation of crop residue (Sharma *et al.* 2001).

2.1.2 Nutrient availability and uptake:

The practice of crop residue management is known to enhance the physico-chemical properties as well as by increasing the nutrient status of the soil (Xu and Yao, 1988). Growing of two cereal crops in a

year yielding more than 10 t ha^{-1} grains involves heavy removal of nutrients from the soil (Hegde and Dwivedi, 1992). They also reported that both rice and wheat are exhaustive feeders of nutrients. A rice-wheat cropping system yield 6-9 t ha^{-1} rice and 3-7 t ha^{-1} of wheat removed as much as 316 kg N, 64 kg P_2O_5 and 401 kg K_2O, apart from significant amount of secondary and micro nutrients.

Sharma *et al.* (1987) reported that application of FYM and plant residues significantly increased total N content and organic carbon contents; the C:N ratio was not affected. The practice of crop residue management is known to enhance the physico-chemical properties as well as by increasing the nutrient status of the soil (Xu and Yao, 1988). Wada *et al.* (1986) observed that only 26% of nitrogen in plants originated from the fertilizer nitrogen, 19% from soil by priming effect of fertilizer and remaining from the soil. They also reported that soil originated nitrogen in plants is composed of rapidly decomposable soil organic nitrogen which contributes about two third of the soil originated nitrogen. This shows the relative significance of decomposable nitrogen compounds added through green manure crops and crops residues.

Sidhu and Beri, (1989) from Punjab reported that alternate additions of rice and wheat residues in rice wheat rotation increased O.C., total N, soluble salts and water holding capacity and decreased pH. Sharma and Mitra (1989) reported that the uptake of N, P, and K by grain and straw of wheat were significantly higher with 20 kg N as starter dose with rice residue incorporation over residue removal.

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Incorporating of residue resulted in 5-10 times more aerobic bacteria an 1.5-11 time more fungi.

Walia *et al.* (1995) concluded that organic carbon content was significantly greater where either residues of wheat or rice both were incorporated over residue removed and residue burnt. No significant change in available nitrogen, phosphorus and potassium was observed. Meelu *et al.* (1994) reported that non-significant effect of residue incorporation on concentration of N, P and K in grain and straw wheat during initial year but the significant increase was seen during subsequent years. Pathak and Sharkar (1994) reported that incorporation of rice residue had non-significant effect on uptake of N.

Walia *et al.* (1997) performed an experiment for management of the crop residue by removal, burning or incorporated in rice wheat rotation in Punjab and concluded that residue management did not affect N, P and K uptake. Sharma and Bali (1998) reported that adding N @ 30 kg ha^{-1} to the decomposing stubbles increased the availability of N, P and K in the soil. Walia *et al.* (1998) concluded that incorporation of rice residues resulted in maximum increase in the O.C. content compared to initial value. Thus management of rice residue could be beneficial through the incorporation method compared to burning and removal.

Singh *et al.* (1998) reported N, P and K concentration were highest at recommended dose of NPK with incorporation of poultry manure and crop residue in grain and straw of wheat. The incorporation of rice straw in wheat and wheat straw in rice improved

soil fertility status as judged by high O.C., available P and K content in comparison to residue removal. Prasad *et al.* (1999) further revealed that residue incorporation was more beneficial than residue burning which resulted in the loss of valuable plant nutrients.

Narang *et al.* (1999) reported that incorporation of the intermediate level of crop residue together with application of the recommended level of N (120 kg ha^{-1}) increased soil organic matter content and available N and P.

Gangaiah *et al.* (1999) conducted a research to study the effect of wheat residue management practices and fertilizer application productivity, nutrient removal and soil fertility of rice-wheat sequence. The total productivity and nutrient removal (N, P and K) were due more with straw incorporation and balanced fertilization with NPK and Zn. Significant increases in percentage organic carbon, available P and K were observed due to straw incorporation. Straw burning also contributed to higher K uptake and higher K content of soil. Organic carbon and total N in the soil increased with the incorporation of crop residue and decreased with burning of crop residue.

Prasad *et al.* (1999) conducted an experiment at IARI, New Delhi in which residue removal, residue burning and residue incorporation were compared. Results obtained showed that both rice and wheat residues can be safely incorporated without any detrimental effects on the crops of rice or wheat grown immediately after incorporation. Incorporation of crop residue also improved soil fertility status as judged by organic carbon and available phosphorus and potassium

contents. Residue incorporation should be preferred over residue burning, which results in the loss of valuable plant nutrients and is both an environmental and a health hazard.

Dhiman *et al.* (2000) found that an increasing trend was recorded in organic carbon content in soil with the incorporation of crop residue. In general, positive improvement in soil fertility status was recorded with residue incorporation. Sharma (2001) reported that when wheat residue was removed from the field, organic C, total N, available P and available K content of soil was either decreased or remained as such at the initial level. Burning of wheat residue *in situ* resulted in the decrease in organic C, total N and available P but an increase in available K content of soil. Incorporation of wheat residue resulted in an increase in organic C, total N, available P and available K content of soil and thus this practice significantly increased soil fertility over the practice of residue removal or burning. Sharma *et al.* (2001) concluded that incorporation of rice residue did not affect P uptake in grain and straw of wheat.

Meena *et al.* (2002) observed that the no significant result was obtained on N uptake by rice grain with straw management practices. There was a significant increase in N uptake by grain and straw due to its successive increment of N up to 120 kg ha^{-1}. Straw incorporation increases native soil P solubility and thus resulted in increased P uptake. Singh (2003) reported that both incorporation of rice straw and addition of straw supplemented with fertilizer application significantly increased in available N and K status of the soil over

control. Organic matter content of the soil increased due to incorporation of both rice and wheat straw. Incorporation of wheat straw had similar effects on the available N and K status of the soil, but proved less beneficial than rice straw.

Gangwar *et al.* (2005) a field study ~~was~~ conducted to evaluate the effect of tillage practices with two nitrogen levels (120 and 150 kg N ha^{-1}) applied in primary strips and three crop residue management practices (removal, burning and incorporation) in secondary strips in wheat after rice. Residue incorporation resulted in highest mean yield (5.86 Mg ha^{-1}) during third year. Maximum mean yield (6.1 Mg ha^{-1}) was obtained in reduced tillage followed by conventional tillage (5.8 Mg ha^{-1}) under residue incorporation in third year. Among crop residue management practices, the highest dry weight of weeds (0.22 Mg ha^{-1}) was recorded under residue incorporation.

Singh *et al.* (2006) reported that initial wheat growth (at 52 DAS) was significantly reduced with straw mulching compared with straw burning or straw incorporation, irrespective of N treatments but the dry matter accumulation at 92 DAS was significantly higher in straw mulch compared with other treatments on sandy loam. This was due to slow rates of soil N mineralization observed under zero-till plots compared with under conventional till plots during the initial four weeks. Mineral N content in 0-45 cm soil layers measured at 58 and 116 days after seeding under 120 kg N ha^{-1} did not differ among tillage and straw management treatments on sandy loam. Grain yield

of wheat was not significantly affected by tillage and straw management.

Bakht *et al.* (2009) reported that post harvest incorporation of crop residues significantly ($p < 0.05$) increased the grain and straw yields of wheat. On an average, crop residues incorporation increased the wheat grain yield by 1.31 times and straw yield by 1.39 times than that in residue removed treatments.

2.1.3 Physico-Chemical properties of soil:

The incorporation of crop residue at low moisture levels was found to decrease soil bulk density in proportion to the amount of straw added (Loganathan, 1975). The organic matter, bulk density relationship was significant at the 20 per cent level (Pant, 1975). However, less than one half of the bulk density variations could be attributed to soil organic matter indicated by the coefficient of determination ($R^2 = 0.479$). Biederbeak *et al.* (1980) reported that burning of the crop residue caused soil compaction that consequently increased in bulk density. Singh and Modgal, (1981) found that incorporation of rice or wheat straw gave lower penetration as compared to rice or wheat straw removed plot.

Gaur *et al.* (1984) reported that available P was favorably affected by the application of FYM in a long term experimental studies. Addition of FYM with inorganic fertilizer increased the organic matter content, available P and K of soil over the years. Application of FYM to rice, wheat and especially to both crop increased the physico-chemical properties of soil. Incorporation of straw of each crop after harvest

improved soil properties (Sharma *et al.,* 1985). Srivastava *et al.* (1987) concluded that the incorporation of organic wastes improved ~~in~~ the organic matter and soil nitrogen status.

Sharma *et al.* (1987) found that incorporation of residue increased the infiltration rate. Crop residue management in rice-wheat cropping system affect the total N, organic carbon, available P (Sharma *et al.,* 1987). They found higher amount of total N, organic carbon, available P in incorporation of residues after 4 crops season than residue removed. Sharma *et al.* (1987) observed that application of FYM and plant residues significantly decreased the soil bulk density, increased the cumulative infiltration rate of water and N, total C content; the C.N rátio was not affected.

Sidhu and Beri (1989) found that incorporation of wheat residue decreased pH and bulk density, and increased total N, organic carbon and water holding capacity. Sidhu and Beri (1989) observed ~~that~~ higher total N and organic carbon, in different crop rotation. pH was decreased with the incorporation of straw in different crop rotation.

Varma and Bhagat (1992) revealed that maximum soil build-up of organic carbon; available N, P and K; and DTP-extractable Zn, Cu, Fe and Mn was observed under straw incorporation + animal manure, followed by animal manure and straw mulch and it was minimum under straw burnt and removal. The treatments of animal manure also resulted in a high percentage of water-soluble aggregates of 70.25 mm in diameter (80.9%), larger mean weight diameter (0.82mm), higher porosity (54.2%) and lower bulk density (1.19 mg m^{-3}).

Beri *et al.* (1992) reported that the residue incorporation increased soil N, P, K, available S, DTP extractable Fe and organic carbon content residue removal decreased soil K, N and Zn contents and increased DTPA-extractable Mn. Burning residues decreased P, DTPA-extractable Fe and Mn, available S and increased K content. Residue management did not affect DTPA-extractable Cu or soil pH. Incorporation of crop residues decreased bulk density and penetration resistance and increased cumulative infiltration rate. Organic carbon content was significantly greater where either residues of wheat or rice or both were incorporated. No significant change in available nitrogen, phosphorus and potassium was observed (Walia *et al.*, 1995).

Walia *et al.* (1998) reported that rice residue incorporation resulted in a positive flux of NPK content in the soil. Incorporation of rice residues resulted in maximum increase in the organic carbon content compared to the initial value. This management of rice residue could be beneficial through the incorporation method compared to burning and removal. Incorporation of groundnut haulm, ~~ha~~ ~~there~~ ~~was~~ considerable improvement in physical properties, i.e. water holding capacity and bulk density of the soil was obtained. (Tiwari *et al.*, 1998).

Gangaiah *et al.* (1999) concluded that significantly increases in percentage O.C., available P and K and a significant decrease in pH of soil were observed due to straw incorporation. Das et al. (2001) reported that incorporation of residue like wheat or rice straw decreased the bulk density and increased the organic matter, cation-exchange

capacity, and hydraulic conductivity, water holding capacity of soil than the initial values.

Kumar *et al.* (2002) observed that hydraulic conductivity, mean weight diameter and aggregation per cent were maximum in green manuring among the main treatments while bulk density and soil strength were maximum in control. In the sub plot treatments, HC, mean weight diameter and aggregation per cent were maximum in puddling with rice husk while bulk density and soil strength were maximum in puddling. It is concluded that green manuring with *S. rostrata* as well as the incorporation of rice husks has a positive effect on the improvement of clay soils.

Rodrigo *et al.,* (2002) reported that crop residue is a valuable resource in Great Plains dryland agroecosystems because it aids in water conservation and soil erosion control. The experiment was conducted with objectives to relate soil and residue parameters to soil C and N levels. There was 3.0 Mg ha^{-1} of residue in the surface 10 cm of soil compared with 2.7 Mg ha^{-1} of residue on the soil surface averaged over ET gradient and cropping systems. About 90% of the residue in the soil was found within the 2.5-cm soil depth. The highest soil organic C (SOC) and soil organic N (SON) were observed in the surface 0- to 2.5-cm depth. The results suggest that higher levels of surface SOC and SON can be attained by increasing cropping intensity and residue incorporation under no-till management.

Gangwar *et al.* (2005) recorded the highest infiltration rate (1.50 cm h^{-1}) under residue incorporation followed by residue burning

(1.44 cm h^{-1}) whereas; the lowest (0.75 cm h^{-1}) in zero tillage. Soil bulk density was the highest (1.69 Mg m^{-3}) under zero tillage and the lowest in residue incorporation (1.59 Mg m^{-3}). Residue incorporation increased soil organic carbon and available P while higher available K was monitored in burning treatment during the third year. Results suggested that reduced tillage and in situ incorporation of crop residues at 5 Mg ha^{-1} along with 150 kg N ha^{-1} were optimum to achieve higher yield of wheat after rice in sandy loam soils of Indo-Gangetic plains of India.

Lal (2005) found that among numerous options for increasing the productivity, the one based on enhancing soil quality and agronomic productivity per unit area through improvement in soil organic carbon pool has numerous ancillary benefits. The available data show that crop yields can be increased by 20-70 kg ha^{-1} for wheat, 10-50 kg ha^{-1} for rice, and 30-300 kg ha^{-1} for maize with every 1 Mg ha^{-1} increase in soil organic carbon pool in the root zone. Adoption of recommended management practices on agricultural lands and degraded soils would enhance soil quality including the available water holding capacity, cation exchange capacity, soil aggregation, and susceptibility to crusting and erosion. Increase in soil organic carbon pool by 1 Mg ha^{-1} y^{-1} can increase food grain production by 32 million Mg y^{-1} in developing countries. While advancing food security, this strategy would also off-set fossil fuel emissions at the rate of 0·5 Pg C y^{-1} through carbons sequestration in agricultural soils of developing countries.

Singh *et al.* (2006) reported that retention of rice straw, compared with straw burning caused a small increase in the soil organic carbon levels in the surface 0-75 mm layer four years after straw incorporation due to rapid carbon turn over rates. Availability of K in the surface 0-75 mm layer was more in case of zero till than conventional till plots at wheat harvest. In conclusion, rice straw can be efficiently managed as straw mulch in zero-till wheat using "Happy Seeder", it will enhance N use efficiency and soil health compared with straw burning in rice-wheat system in the Indo-Gangetic plains of India.

Sharma *et al.* (2009) found that the crop residue retention on the soil surface has multifarious benefits. It conserves soil moisture, moderates temperature, suppresses weeds, improves soil physicochemical properties and helps to make the system sustainable. Rotary powered disc drill and happy seeder are machines capable of seeding in to full crop residue. The rotary disc drill can also ~~seed in the~~ help in increasing the cropping intensity and ultimately the farm profitability. It will also help in increasing the area under wheat for national food security. In addition, the benefits of residue retention in increasing soil organic carbon and reducing soil strength and weed infestation can go a long way in making the rice-wheat system sustainable. However, further intensive investigations are required on the residue load that can be sustained for a long time, as well as the potential effects on insect pests, disease and weeds.

2.2 Effect of nutrient management on crop:

2.2.1 Growth and development of wheat:

Singh (1964) did not found any significant effect of nitrogen alone or in combination with phosphorus on the initial plant stand of wheat crop. Singh *et al.* (1968) also noted that application of nitrogen did not affect the germination of wheat significantly. Gill *et al.* (1971) and Mishra and Singh (1971) reported that application of nitrogen did not affect the germination of wheat. Singh (1980) did not find any significant effect of nitrogen fertilization upto 120 kg ha $^{-1}$ on the initial plant stand of wheat in sandy loam soils of Agra. Sharma *et al.* (1981) observed that nitrogenous fertilizer application significantly affect the seedling emergence adversely under rainfed condition. Kumar (1985) reported that nitrogen levels did not cause any significant variation in the number of plants per running metre. Although the number of plants were slightly decreased with increase in the dose of nitrogen. Pandey *et al.* (1998) reported that nitrogen level did not affect the germination.

Agrawal and Moolani (1978) revealed that plant height of wheat increased with increasing levels of nitrogen. Singh *et al.* (1980) concluded that the height of main shoot of wheat was increased by 29 per cent with 120 kg N ha^{-1} over no nitrogen. Further they pointed out that in general, plants attained very nominal height within the first 30 days. From 30 to 90 days of sowing plant gained very rapid increase in height and further rate of increase was slow till harvest. Baliyan *et al.* (1984) working on zero and conventional tillage under different levels

of nitrogen in wheat sown after cotton, reported that there was significant increase in the height of crop with successive increase in nitrogen application upto 120 kg N ha^{-1}. Kumar (1985) noted that plant height increased with increase in nitrogen upto 120 kg N ha^{-1} during first year while in the subsequent years, it increased upto 180 kg ha^{-1} but was on par with 120 kg N ha^{-1} under late sown condition. Hooda and Agrawal (1987) working on sandy loam soils of Hisar reporter that application of 120 kg N ha^{-1} significantly increased the plant height over 60 kg N ha^{-1} at all the stage of crop growth. Singh and Singh (1987) working on sandy loam soils of Bulandshahar reported that growth of wheat increased significantly with increasing levels of N upto 120 kg N ha^{-1} as compared to 0,40 and 80 kg ha^{-1}. Singh and Singh (1989) revealed that significantly higher plant height was recorded at 160 kg N ha^{-1}. Khan *et al.* (1990) reported that significantly higher plant height was noted with 120 kg N ha^{-1} over 60 kg N ha in the deep sandy loam soils of Morena, M.P.

Kumar *et al.* (1995) working on sodic soils of Karnal reported that increasing levels of N from 0 to 180 kg ha^{-1} increased the plant height. Patel *et al.* (1995) reported an increase in plant height up to 150 kg N ha^{-1}. Singh and Bhan (1998) observed that plant height was favorably affected by increasing levels of nitrogen. Kataria *et al.* (1999) concluded that nitrogen @ 80 kg ha^{-1} significantly produced taller plants over 40 kg N ha^{-1}. Das *et al.* (2001) reported that application of 75% and 100% NPK gave higher plant height over 0 and 50 % NPK.

Increasing level of nitrogen up to 100 kg ha^{-1} produced taller plants (Saren and Jana 2001).

Relwani and Kataria (1966) observed that balanced nutrition to dwarf wheat variety Sonara 64 increased the number of tillers per plant. Number of tillers per square meter was increased by the application of nitrogen (Sandhu and Gill, 1972). Chandavanshi and Singh (1974) observed that an increment in the number of tillers with increasing levels of nitrogen application. Singh and Singh (1975 a) obtained ~~that~~ significant~~ly~~ increase in the number of tillers $metre^{-1}$ row length up to 150 kg N ha^{-1} in loamy soils of the Varanasi. Singh *et al.* (1980) found that tiller production in wheat was improved by 33.2 per cent under 120 kg N ha^{-1} over no nitrogen in sandy loam soils. Spiertz *et al.* (1983) reported that early top dressing of high levels of nitrogen stimulate tillers formation and leaf area growth resulted in increasing shoot dry weight and leaf area index. Application of nitrogen at 120 kg ~~N~~ ha^{-1} gave maximum tillers $plant^{-1}$ reported by Panda *et al.* (1988). Verma *et al.* (1988) reported that the beneficial effect of nitrogen on yield could be seen through more effective tillers.

Bhagwati *et al.* (1990) observed ~~that~~ increasing growth of wheat in terms of number of shoot m^{-2} and dry matter accumulation in fertilized plots. Roy *et al.* (1991) indicated that number of tillers per plant increased with an increas~~ing~~ in nitrogen levels up to 120 kg N ha^{-1}. Singh *et al.* (1992) reported that increasing level of N increased the tillers m^{-1} row length. Singh and Agrawal (2001) revealed that application of graded levels of nitrogen (0, 60, 120, 180 kg N ha^{-1} and

120+60+25 kg NPZn ha^{-1} i.e. recommended dose of fertilizer) and recommended dose of NPZn fertilizer significantly enhanced number of tillers per plant at 45 DAS.

Singh and Gupta (1970) pointed out that dry matter accumulation was rapid between 90 and 120 day of plant growth at different levels of nitrogen in tarai conditions. Singh and Anderson (1973, 1975 and 1978) noticed that dry matter accumulation in plant increased significantly with an increased application of nitrogen, the difference being narrow at early stages and wider towards maturity. Further, they pointed out that active vegetative growth was almost completed at 90 days after sowing. Lal and Sharma (1973) reported that dry weight increased slowly during early stages and rapid between 90 and 120 days of plant growth. Waldren and Flowerday (1979) observed that dry matter accumulation increased rapidly from jointing to dough stage and 80 percent of total dry matter accumulation took place by grain filling stage in wheat. Dear *et al.* (1979) working on nitrogen and phosphorus of wheat sown in rice stubble under minimum tillage condition found that dry matter accumulation continued up to 120 kg N ha^{-1}. Singh (1980) noticed that dry matter production significantly increased with nitrogen fertilization in dwarf wheat, further, he pointed out that significantly higher dry matter production was found with 120 kg N ha^{-1}, being 86.3 percent more over control. Dry matter yield was obtained significantly higher under 120 kg N ha^{-1} as compared to half of its dose at all the stages in the sandy loam soils of Hissar (Hooda and

Agrawal, 1987). Panday *et al.* (1998) reported that application of nitrogen at 100 kg ha^{-1} gave significantly higher dry matter accumulation over lower nitrogen levels. Kataria *et al.* (1999) revealed that higher dry matter accumulation was recorded with 80 kg N ha^{-1} over 40 kg N ha^{-1}. Kumar and Sharma (1999) observed that the crop accumulated 9% dry matter during first 40 DAS, 31% dry matter between 40 and 60 DAS, and 49% dry matter from 80 DAS to maturity. The peak period of their accumulation (47-49%) being from 60 to 80 DAS. While, N application significantly increased the dry matter production. Auti *et al.* (1999) reported that maximum dry matter production was recorded with recommended dose of fertilizer (120:60:60 kg NPK ha^{-1}) over lower dose of fertilizer. Singh and Agrawal (2001) revealed that significantly higher dry matter was recorded with recommended dose of N, P and Zn ha^{-1}.

Sharma *et al.* (1993) reported that root penetration was faster to a great depth with 120 kg and 180 kg N ha^{-1} than 0 and 60 kg N ha^{-1} as well as rooting density in the surface layers increased with increase in nitrogen level.

Kataria *et al.* (1999) observed that heading and maturity were delayed by 4 days by increasing N from 40 to 80 kg ha^{-1}.

2.2.2 Yield attributing characters:

Singh (1967) recorded a significant increase in the number of effective tillers per unit area due to N application. Gill *et al.* (1971) noted that nitrogen fertilization had positive significant effect on the number of ear bearing tillers in wheat under Ludhiana conditions.

An application of 80 kg N ha^{-1} significantly increased the number of earheads over no nitrogen application (Chandrashekariah *et al.*, 1971). Singh (1980) reported that number of ear bearing shoots per metre row length in wheat was increased by 39.44 per cent with 120 kg N ha^{-1} over control.

Singh (1986) from Faizabad observed that an application of 100 kg N ha^{-1} to wheat significantly increased the number of spike bearing tillers m^{-2} as compared to lower dose of nitrogen. The magnitude of increase was higher by 18 and 12.9 per cent during first and second years of investigation, respectively, under late sown conditions.

Singh and Verma (1990) working on clay loam soils of Sehore (M.P.) reported that the number of effective tillers per plant increased significantly with an increase in nitrogen application from 0 to 180 kg N ha^{-1}. Singh *et al.* (1991) working on sand loam soils of Ambikapur (M.P.), reported that number of effective tillers per plant increased significantly with increase in nitrogen levels upto 40 kg ha^{-1}.

Kumar *et al.* (1995) working on sodic soil of Karnal reported that productive tillers were significantly increased with increase in nitrogen levels from 0 to 120 kg N ha^{-1}. Singh *et al.* (1995 a) from Jammu and Kashmir reported a significant increase in the number of effective tiller m^{-2} with successive increase in nitrogen levels from 40 to 120 kg ha^{-1}. Patel *et al.* (1995) also observed an increas~~ing~~e in effective tillers/ m row length till 150 kg N ha^{-1}. Kataria *et al.* (1999) reported that more number of effective tillers were recorded with 8 kg N ha^{-1} over 40 kg ha^{-1}. Auti *et al.* (1999) pointed out the maximum effective tillers were

recorded with recommended dose of fertilizer (120:60:60 kg NPK). Application of recommended dose of fertilizer (120:60:40 kg NPK ha^{-1}) gave better response in term of effective tillers reported by Dwivedi and Thakur (2000).

Das *et al.* (2001) reported that significantly maximum effective tillers m^{-2} was recorded with 100% NPK level. Significantly maximum number of effective tillers was recorded with 100 kg N ha^{-1} Saren and Jana (2001). Singh and Agrawal (2001) revealed that recommended dose of NPZn (120+60+25 kg NPZn ha^{-1}) produced significantly maximum effective tillers.

Sharma and Singh (1966) observed that increasing level of nitrogen markedly increased the ear length of wheat. Singh (1980) observed significant increase in ear length up to the extent of 39.24 percent with 120 kg N ha^{-1} over control.

Kumar (1985) reported that application of 120 kg N ha^{-1} significantly increased the length of ear head under late sown condition. Singh and Verma (1990) working on clay loam soils of Sehore (M.P.) reported that the ear length of wheat increase significantly with an increase in nitrogen levels from 0 to 180 kg N ha^{-1}. Khan *et al.* (1990) working on deep sandy loam soils of M.P. reported that application of 120 kg N ha^{-1} gave significantly more ear length over 60 kg N ha^{-1}.

Patel *et al.* (1995) observed an increase in length of spike till 150 kg N ha^{-1}. Kataria *et al.* (1999) reported that application of 80 kg N ha^{-1} resulted in longer ears. Auti *et al.* (1999) observed that length of ear

significantly increased with increasing level of fertilizer i.e. 120, 60 and 60 kg N, P_2O_5 and K_2O ha^{-1}. Dwivedi and Thakur (2000) revealed that significantly longer ear length was obtained with the application recommended fertilizer level (120, 60 and 40 kg N, P and K ha^{-1}) to wheat in both the years. Das *et al.* (2001) reported that ear length significantly maximum with application of recommended dose of fertilizer.

Sharma and Singh (1966) reported that increasing fertility levels for dwarf wheat significantly increased the number of grains. and spikelets per ear. Agarwal and Yadav (1978) stated ~~obtained~~ that application of 80 to 120 kg N ha^{-1} significantly increased spikelets ear^{-1} and grains per spike. Dhiman *et al.* (1982) concluded that the number of spikelets $spike^{-1}$ was significantly influenced by nitrogen rates. Singh and Verma (1990) working on clay soils of Sehore (M.P.) reported that number of grains per ear increased significantly with an increase in nitrogen application from 0 to 180 kg N ha^{-1}.

Kumar *et al.* (1995) working on sodic soils of Karnal concluded that number of grain per spike increased with increase in nitrogen levels from 0 to 120 kg N ha^{-1}. Singh *et al.* (1995) from Jammu and Kashmir reported a significant increase in the number of grains ear^{-1} of wheat with increase in nitrogen levels from 40 to 120 kg N ha^{-1}. Patel *et al.* (1995) also observed an increase in spikelets $spike^{-1}$, grains $spike^{-1}$, grain weight $spike^{-1}$ till 150 kg N ha^{-1}.

Singh *et al.* (1997) reported that application of 120 kg N ha^{-1} produced maximum grains $spike^{-1}$. Singh and Bhan (1998) observed

that grain weight spike^{-1} of wheat favourably affected by nitrogen levels. Kataria *et al.* (1999) revealed that application of 80 kg N ha^{-1} resulted in more number of grains ear^{-1}. Auti *et al.* (1999) reported that more number of grains panicle^{-1} and grain weight panicle^{-1} were increased significantly with increase in levels of NPK. Dwivedi and Thakur (2000) found significantly higher grain weight ear^{-1}, spilkelets ear^{-1} and number of grains ear^{-1} with the application of recommended fertilizer level (120, 60 and 40 kg NPK ha^{-1}) to wheat in both year. Saren and Jana (2001) reported that significantly higher grains panicle^{-1} recorded with 100 kg N ha^{-1}. Singh and Agrawal (2001) observed that application of graded levels of nitrogen and recommended dose of NPZn produced significantly maximum number of grains spike^{-1}.

Sharma *et al.* (1971) reported that 1000-grain~~s~~ weight was significantly higher in dwarf wheat due to application of nitrogen. Chandrasekharaih *et al.* (1971) found that application 80 kg N ha^{-1} considerably increased the 1000-grain~~s~~ weight. Tomar (1977) noted that 1000-grain weight was recorded significantly higher with the application of 120 kg N ha^{-1} as compared to 60 kg N ha^{-1}.

Singh *et al.* (1980) found an increase in test weight with increasing levels of nitrogen. Kumar (1985) reported that 1000-grain~~s~~ weight showed marked improvement due to nitrogen application under late sown conditions. Singh (1986) found th~~e~~at application of 100 kg N ha^{-1} enhanced the test weight significantly under late sown condition. Singh *et al.* (1995) from Jammu and Kashmir concluded

from two years investigation in silt clay loam soils that significant increase in 1000-grains weight was observed with increase in nitrogen levels from 40 kg to 120 kg N ha^{-1}. Patel *et al.* (1995) reported that increase in test weight with increasing levels of nitrogen up to 150 kg N ha^{-1}. Singh *et al.* (1997) reported that application of 90 kg N ha^{-1} resulted in maximum 1000-grain weight. Application of 80 kg N ha^{-1} found maximum test weight over 40 kg N ha^{-1}, non-significant differences between 80 and 120 kg N ha^{-1}were observed (Kataria *et al.*, 1999). Auti *et al.* (1999) revealed that 1000-grain weight was increased with increase in levels of NPK.

Dwivedi and Thakur (2000) observed that significantly higher 1000-grain weight was obtained with the application of recommended dose of fertilizer. Nitrogen @ 100 kg ha^{-1} recorded higher test weight by Saren and Jana (2001).

2.2.3 Yield:

Singh *et al.* (1971) reported that under late sown conditions, semi dwarf and dwarf wheat varieties gave significantly higher yield with 120 kg N ha^{-1}. Sharma *et al.* (1971) indicated that application of 120 kg N ha^{-1} produced significantly higher grain~~s~~ yield under late sown conditions.

Patel *et al.* (1982) reported that grain yield of wheat increased significantly with each successive level of nitrogen from 0 to 120 kg N ha^{-1}. The application of 120 kg N ha^{-1} recorded the grain yield by 36 q ha^{-1}. Dhiman *et al.* (1982) observed that significantly higher grain yield was recorded with 120 kg N ha^{-1} as compared to lower doses.

Malvia *et al.* (1987) found that the grain yield of wheat increased significantly with 120 kg N ha^{-1} as compared to 0, 60 and 180 kg N ha^{-1} in the medium clay soils of Junaga~~rh~~dh. Sharma and Dhillon (1987) working on loamy soils of Ludhiana reported that grain yield increased with increasing levels of nitrogen from 0 to 160 kg N ha^{-1} but significant increase was recorded up to 120 kg N ha^{-1}, further increase in dose of N had no significant effect.

Verma *et al.* (1988) working on silt loam soils of Ranchi concluded that grain yield increased successively with increase in nitrogen levels from 25 to 100 kg ha^{-1} attributed to increase in yield attributes viz., effective tillers m^{-2}, spike length and number of grains $spike^{-1}$. Parihar and Tripathi (1989) from Kharagpur reported that there was favorable response of 150 kg N ha^{-1} on the grain yield of wheat as compared to lower levels of nitrogen in the sandy clay loam soils. Soni *et al.* (1989) from Sehore (M.P.) reported that nitrogen application had significant influence on the grain and straw yield of wheat. Highest grain yield of 29.0 q ha^{-1} was recorded when crop fertilized with 125 kg N ha^{-1} as compared to rest of nitrogen levels. The grain yield obtained with 125 kg N ha^{-1} was increased by 78.6, 37.0 and 16.2 per cent higher over control, 75 kg and 100 kg N ha^{-1} respectively.

Singh and Verma (1990) working on clay loam soils of Sehore (M.P.) reported that grain yield of wheat increased significantly with increase in nitrogen from 0 to 180 kg N ha^{-1}. Higher grain yield was recorded under 120 kg nitrogen application as compared to 60 kg N ha^{-1} in the deep soils of Morena, M.P. (Khan *et al.*, 1990). ~~Dukha~~ Dhaka *et al.*

(1992) working on loamy sand soils of Junaga~~rh~~dh reported that both grain and straw yields of wheat increased with increase in nitrogen levels from 40 kg to 120 kg ha^{-1} due to enhanced physiological activities of the plants caused by increased nitrogen uptake under higher nitrogen application.

Awasthi and Surajbhan (1993) reported that the application of 60 kg N ha^{-1} resulted in the maximum yield which was significantly higher than that obtained with 0, 20 and 40 kg N ha^{-1}. Singh and Barar (1994) working on sandy loam soils of Ludhiana concluded that grain and straw yield of wheat increased significantly with successive increase in nitrogen from 60 kg to 120 kg ha^{-1}. Kumar *et al.* (1995) working at sodic soils of Karnal reported that grain yield of wheat significantly increased with each successive increase in nitrogen level from 0 to 180 kg ha^{-1} over the control.

Singh *et al.* (1995) working on silt clay loam soils of Kashmir reported that the grain yield of wheat increased significantly up to 120 kg N ha^{-1} over the control. The increase in yield may be attributed to increase of spikes m^{-2}, grains ear^{-1} and 1000-grain weight. Increment of each level of nitrogen from 60 to 180 kg ha^{-1}, there was significant increase in grain yield observed by Kumar *et al.* (1995). Upahyay and Tiwari (1996) reported that application of 120 kg N ha^{-1} gave the maximum yield. Sharma and Acharya (1997) pointed out ~~the~~ that yield ~~were~~ was significantly affected by N level up to 120 kg N ha^{-1}. Crop responded significantly up to 60 and 90 kg N ha^{-1} for grain and straw yield respectively reported by Singh *et al.* (1997). Pandey *et al.* (1998)

observed that the highest level of nitrogen (100 kg N ha^{-1}) resulted in significantly higher grain yield than the lower levels. Increasing level of nitrogen increased the grain yield as reported by Singh and Bhan (1998).

Pandey *et al.* (1999) pointed out the grain and straw yield increased significantly by recommended dose of NPK (100 kg, N, 50 kg P and 25 kg K ha^{-1}). Application of 80 and 120 kg N ha^{-1} were resulted significantly maximum grain and straw yield reported by Kataria *et al.* (1999). Auti *et al.* (1999) reported that grain and straw yield were increased significantly with the increase in levels of NPK. Kumar *et al.* (2000) revealed that the application of nitrogen @ 120 kg N ha^{-1} exerted positive effects on yield of wheat. Higher fertility level (150+60+25 kg N, P_2O_5 and $ZnSO_4$ ha^{-1}) registered significantly higher grain yield than lower levels of fertilizers. Significantly higher grain yield was obtained with the application of recommended fertilizer level (120, 60 and 40 kg N, P and K ha^{-1}) to wheat reported by Dewivedi and Thakur (2000). Verma (2001) reported an improvement in grain yield of wheat with the application of higher dose (150 kg/ha) of nitrogen.

Increasing levels of NPK applied in rice increased grain and straw yield as pointed out by Das *et al.* (2001). Saren and Jana (2001) reveal that the nitrogen @ 100 kg ha^{-1} produced significantly higher grain and straw yield. Highest level of NPK significantly increased the grain and straw yield reported by Bastia *et al.* (2001). Singh and Agrawal (2001) reported that grain and straw yields significantly increased with graded level of nitrogen. Das *et al.* (2003) revealed that

the increasing levels of NPK application increased the grain and straw yields.

Singh *et al.* (2006) reported that N use efficiency was lower on zero-till plots when straw was either burned or removed compared with straw incorporation and straw mulch treatments, particularly at low N rates. Grain yield of following rice was not influenced by the tillage and straw management treatments applied to wheat on sandy loam. But grain yield of rice was significantly lower where rice straw was removed than when it was retained, particularly at low N rates applied in preceding wheat. Mineral N content in 0-45 cm soil layers measured at 58 and 116 DAS under 120 kg N ha^{-1} did not differ among tillage and straw management treatments.

2.2.4 Nitrogen uptake by crop:

Many wheat researchers observed that nitrogen uptake by wheat significantly increased with increasing levels of nitrogen.

The maximum value of nitrogen uptake was recorded with 90 kg N ha^{-1} by Black (1970), 120 kg N ha^{-1} by Singh (1975) and Singh *et al.* (1979, 1980) and 150 kg N ha^{-1} by Singh and Singh (1975b). Singh and Seath (1978) found that nitrogen accumulation in wheat plant was significantly increased with increasing dose of nitrogen.

Singh *et al.* (1987) from Hissar reported that increasing level of nitrogen application resulted in continuous increase in nitrogen uptake by grain and straw. ~~Dukha~~ Dhaka *et al.* (1992) working on loamy sand soils of Junaga~~rh~~dh reported that increasing levels of nitrogen from 40 kg to 120 kg N ha^{-1}, significantly increased the nitrogen uptake by

grain and straw of wheat. With each increment of nitrogen level ~~form~~ from 60 to 180 kg ha^{-1}, there was significant increase in nitrogen uptake and N-use efficiency ~~were maximum with 60 kg N ha^{-1}~~ reported by Kumar *et al.* (1995). Significant improvement due to increased levels of NPK was also noticed for uptake of nutrients by Auti *et al.* (1999).

Maximum nitrogen uptake was recorded with increasing level of NPK by Dwivedi and Thakur (2000). Saren and Jana (2001) revealed that the application of 100 kg N ha^{-1} resulted in maximum N, P and K uptake in straw as well as grain of wheat crop. Increase in N levels up to 120 kg N ha^{-1} also depicted gradual increase both in N-concentration and N-uptake by Kumar *et al.* (2000). Das *et al.* (2003) observed that increasing level of NPK application increased the nutrient uptake by grain and straw.

Bakht *et al.* (2009) reported that application of N fertilizer to wheat produced on an average 1.59 times more grain and 1.77 times more straw yield over the no nitrogen ~~0 N kg ha^{-1}~~ treatment. The N uptake in wheat grain and straw was increased 1.31 and 1.64 times by residues treatment, 2.08 and 2.49 times by mung bean and 1.71 and 1.86 times by N fertilizer ~~N~~ applied to wheat, respectively. The soil mineral N was increased 1.23 times by residues, 1.34 times by mung bean and 2.49 times by the application of N fertilizer ~~N~~ to wheat. Similarly, the soil organic C was increased 1.04-fold by residues, 1.08 times by mung bean and 1.00 times by the application of N fertilizer ~~N. We~~ It can be concluded that retention of residues, application of N fertilizer ~~N~~ and involvement of

legumes in crop rotation greatly improves the N economy of the cropping system and enhances crop productivity in low N soils.

2.2.5 Protein content:

Like nitrogen uptake, positive effect on grain protein was noted by Jaisinghani *et al.* (1970) and Dutta and Seth (1970).

Singh and Singh (1975) reported that protein content of wheat increased with increasing doses of nitrogen values of protein being 10.7 per cent at 50 kg N ha^{-1}, 12.5 per cent at 100 kg N ha^{-1} and 14.3 per cent at 150 kg N ha^{-1}. Bildik and Ercan (1994) in field trial ~~in~~ Turkey ~~on wheat~~ during 1990. ~~They were given~~ applied 0, 30, 60, 90 and 120 kg N ha^{-1} ~~as~~ ammonium nitrate at sowing time. They found that grain protein content increased with nitrogen rate.

Pandey *et al.* (1999) revealed that the protein content increased significantly up to the recommended dose of fertilizer protein content was significantly increased with the increase in levels of NPK reported by Auti *et al.* (1999). Increasing level on NPK increased the protein content observed by Dwivedi and Thakur (2000).

Chapter three

MATERIAL AND METHODS

Chapter-III

MATERIAL AND METHODS

The field experiment entitled **"Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice – wheat sequence"** was conducted during *rabi* season of 2007-08 and 2008-09. The materials and techniques employed in conducting the experiment are described in this chapter.

3.1 Experimental site:

The field experiment was conducted at the Research Farm of Brahmanand Post Graduate College, Rath (Hamirpur) U.P. The Research Farm is situated in the southern part of Uttar Pradesh in Bundelkhand region. The field has good drainage with moderate slope in one direction from east to west.

3.2 Geographical situation:

Geographically the experimental station is located at latitude of 79.7^0 East and longitude of 25.5^0 North at an elevation of 17526 ft. from mean sea level.

3.3 Climate and season:

Bundelkhand has subtropical climate with extreme hot days in summer and cold in winter. The average weekly maximum and minimum temperature, relative humidity, rainfall, wind velocity,

sunshine hours and evaporation during crop period for both the years are given in Table 3.1 and 3.2.

Table 3.1: Meteorological observations (standard week-wise) recorded during crop season (2007-2008)

Standard week No.	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Wind velocity (km h^{-1})	Sunshine (hours)	Evapor-ation (mm)
		Max.	Min.	Max.	Min.			
42	0.0	34.3	14.4	76	30	3.0	8.8	4.8
43	0.0	35.0	12.7	78	22	2.4	8.6	4.9
44	0.0	32.8	11.8	81	28	2.2	8.1	4.3
45	0.0	33.2	11.7	88	24	1.6	7.6	3.4
46	0.0	31.2	11.1	88	27	2.0	7.5	3.0
47	0.0	28.3	8.4	84	29	2.0	7.1	2.9
48	0.0	28.3	8.8	90	35	1.7	5.8	2.9
49	0.0	23.8	7.6	92	48	1.6	5.0	2.0
50	0.0	23.6	7.2	91	45	2.8	3.4	2,0
51	0.0	24.0	3.7	84	31	2.7	8.3	2.6
52	0.0	24.5	5.4	84	35	2.1	3.0	2.5
01	0.0	21.1	4.9	89	39	1.5	4.6	1.8
02	0.0	24.4	6.5	89	40	2.7	4.9	2.3
03	0.0	24.8	5.9	85	36	3.6	6.9	2.6
04	0.0	18.8	2.3	90	46	2.3	6.0	2.0
05	0.0	20.7	4.1	90	41	2.4	7.6	2.3
06	0.0	22.8	5.6	87	41	4.2	7.9	2.6
07	0.0	24.9	2.6	86	35	2.4	10.1	3.1
08	0.0	28.5	6.4	85	33	2.9	9.0	3.6
09	0.0	30.8	6.1	79	22	2.9	9.8	4.4
10	0.0	34.1	10.3	85	24	2.5	9.3	4.7
11	0.0	32.6	11.4	76	22	3.3	7.1	5.0
12	0.0	36.2	14.6	80	22	3.7	9.0	6.2
13	0.0	36.6	16.7	61	18	5.9	7.6	6.9

Table 3.2: Meteorological observations (standard week-wise) recorded during crop season (2008-2009)

Standard week No.	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Wind velocity (km h⁻¹)	Sunshine (hours)	Evaporation (mm)
		Max.	Min.	Max.	Min.			
42	0.0	34.2	14.2	76	31	3.1	8.6	4.6
43	0.0	35.0	12.6	77	23	2.5	8.5	4.5
44	0.0	32.6	11.7	82	28	2.3	8.3	4.1
45	0.0	33.1	11.8	85	23	1.7	7.5	4.0
46	0.6	31.3	11.2	82	26	2.1	7.6	3.2
47	0.0	28.5	8.3	84	29	2.3	7.3	2.7
48	0.0	28.5	8.9	90	36	1.8	5.9	2.6
49	0.0	23.7	7.7	95	48	1.6	5.1	2.1
50	0.0	23.5	7.1	94	46	2.6	3.2	2.1
51	0.0	24.0	3.7	84	33	2.8	8.2	2.5
52	0.0	24.4	5.5	83	35	2.1	3.1	2.4
01	0.0	21.1	5.0	89	38	1.4	4.6	1.7
02	0.0	24.5	6.4	87	40	2.6	4.5	2.1
03	0.0	24.8	5.8	85	37	3.5	6.8	2.7
04	0.8	18.9	2.3	90	46	2.2	6.1	2.1
05	0.0	20.6	4.2	91	42	2.3	7.6	2.6
06	0.0	22.8	5.6	87	41	4.1	7.8	2.7
07	0.0	24.9	2.7	86	36	2.4	10.2	3.2
08	0.6	28.5	6.5	87	33	2.4	9.6	3.7
09	0.0	30.7	6.2	79	23	2.8	9.8	4.5
10	0.0	34.1	10.2	86	24	2.4	9.5	4.5
11	0.0	32.5	11.6	76	23	3.8	7.0	5.1
12	0.0	36.2	14.7	81	22	3.6	9.3	6.3
13	0.0	36.7	16.4	63	17	5.1	7.5	6.5

Figure 3.1: Meteorological observations (standard week-wise) recorded during crop season (2007-2008)

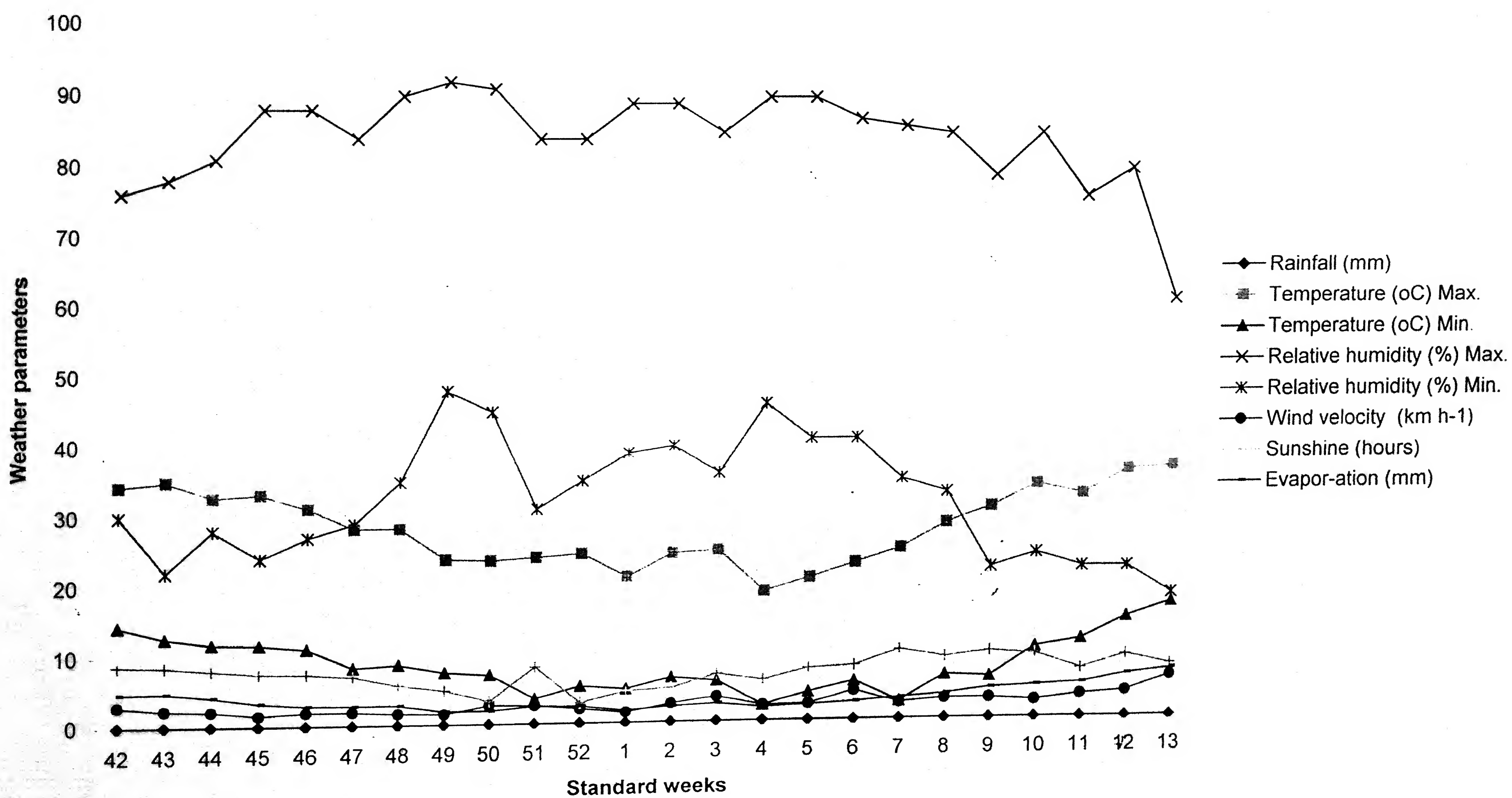
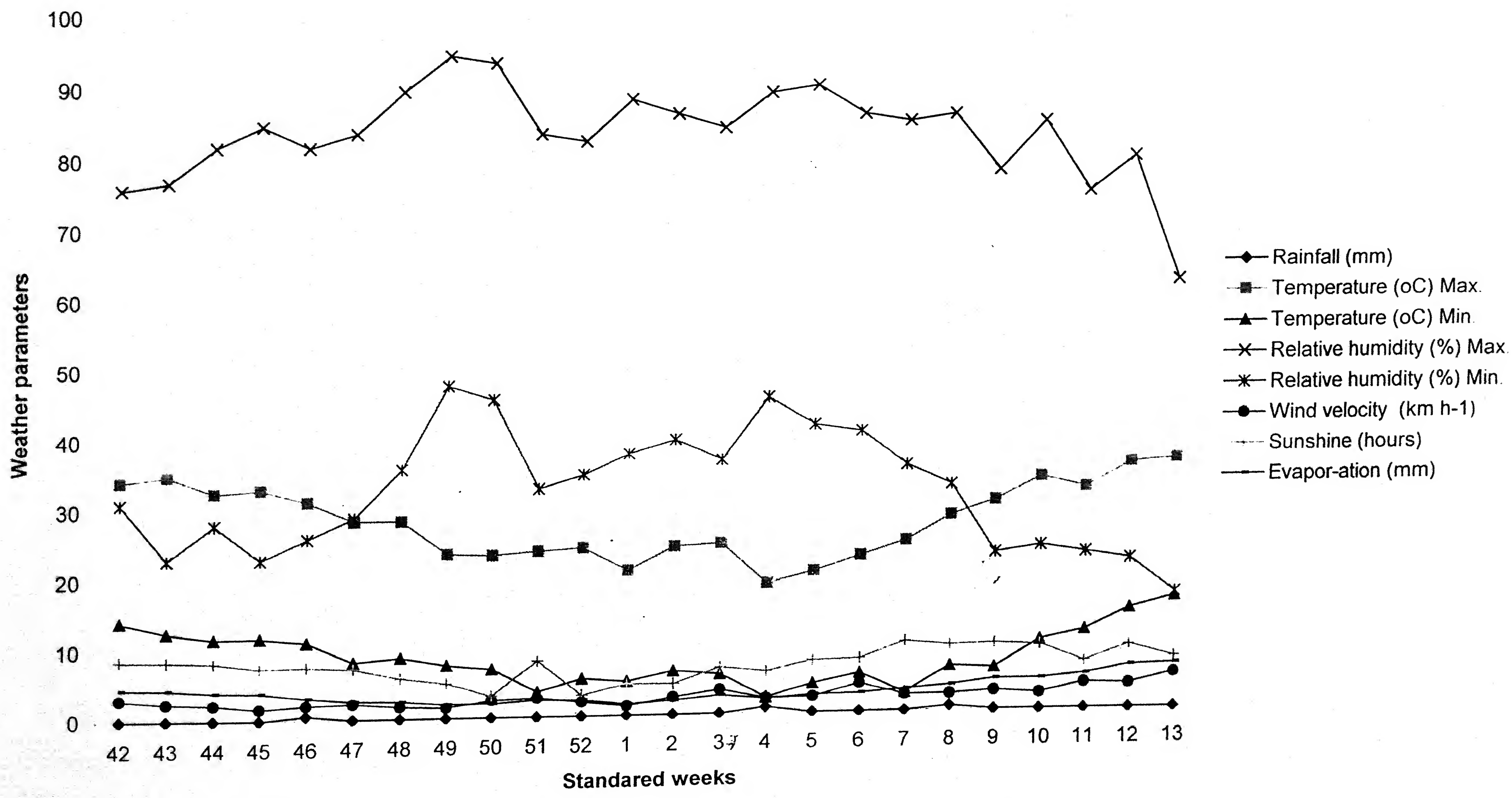


Figure 3.2: Meteorological observations (standard week-wise) recorded during crop season (2008-2009)



3.4 Cropping history of the experimental field:

Before starting the present investigation the cropping history of the field for last 5 years was carefully examined to know the nature of crop grown and has been summarized in Table 3.3.

3.5 Soil of the experimental field:

The physico-chemical properties of soil was analyzed from the soil samples collected at random from different places with the help of a soil auger to a depth of 15 cm prior to application of fertilizers. Soil samples were mixed properly and a composite sample was drawn for analysis. The results of mechanical and chemical analysis are given in Table 3.4 and 3.5.

Table 3.3: Cropping history of the experimental field

S. No.	Year	Crops grown		
		Kharif	*Rabi*	*Zaid*
1.	2002-2003	Rice	Wheat	-
2.	2003-2004	Urd	Pea	-
3.	2004-2005	Maize	Wheat	-
4.	2005-2006	Soybean	Pea	-
5.	2006-2007	Rice	Wheat	-
6.	2007-2008	Rice	Experimental crop	-
7.	2008-2009	Rice	Experimental crop	-

3.5.1 Mechanical analysis

The mechanical analysis of soil was done by "Hydrometer method" as described by Bouyoucos (1936). The results, thus obtained have been presented in Table 3.4.

Table 3.4: Mechanical analysis of the experimental soil

S. No.	Fraction	Value (%)		Method of analysis
		2007-08	2008-09	
1-	Sand	27.31	26.25	Hydrometer method (Bouyoucos, 1936)
2-	Silt	49.09	50.25	
3-	Clay	23.6	23.5	
4-	Textural Class	Silt Loam Paruwa		Triangular method (Lyon *et al.*, 1952)

3.5.2 Chemical analysis

The composite soil samples used in mechanical analysis was also analyzed for available nitrogen, phosphorus and potash, organic carbon, soil pH and electrical conductivity (EC) by the method as mentioned against each property of soil in Table 3.5.

It is clear from Table 3.~~6~~5 that the soil of experimental field was medium in organic carbon and low in available nitrogen, medium in phosphorus and potassium. The pH and EC of soil were 7.8 and 0.34 during 2007-08 and 7.~~8~~7 and 0.3~~8~~5 during 2008-09, respectively.

Table 3.5: Chemical analysis of the experimental soil

S. No.	Fraction	2007-08	2008-09	Method of analysis
1-	Available nitrogen (kg ha^{-1})	117.37	121.15	Alkaline permanganate method (Subbiah & Asija, 1956)
2-	Available Phosphorus (kg ha^{-1})	16.62	17.65	Olsen's method (Olsen *et al.*, 1954)
3-	Available Potash (kg ha^{-1})	261.0	268.50	Neutral- N-ammonium acetate using Flame Photometer (Jackson, 1973)
4-	Organic Carbon (%)	0.24	0.26	Walkley and Black's Rapid Titration method (Walkley and Black, 1934)
5-	Soil pH (1:2.5)	7.8	7.7	Glass electrode pH meter method No. 21 USDA, Hand Book No. 60, p. 102 (Richards,1954)
6-	Electrical Conductivity (1:2.5) (dSm^{-1})	0.34	0.35	Conductivity meter method No. 4 USDA, Hand Book No. 60, p. 89 (Richards,1954)

Not mentioned in Lit. cited.

3.6 Lay out plan

Detailed layout plan was presented in Figure 3.3

3.7 Details of treatments and their symbols

There were 14 treatments consisting of within recommended dose and over and above recommended dose. The details of the treatments with their symbols are given in Table 3.6.

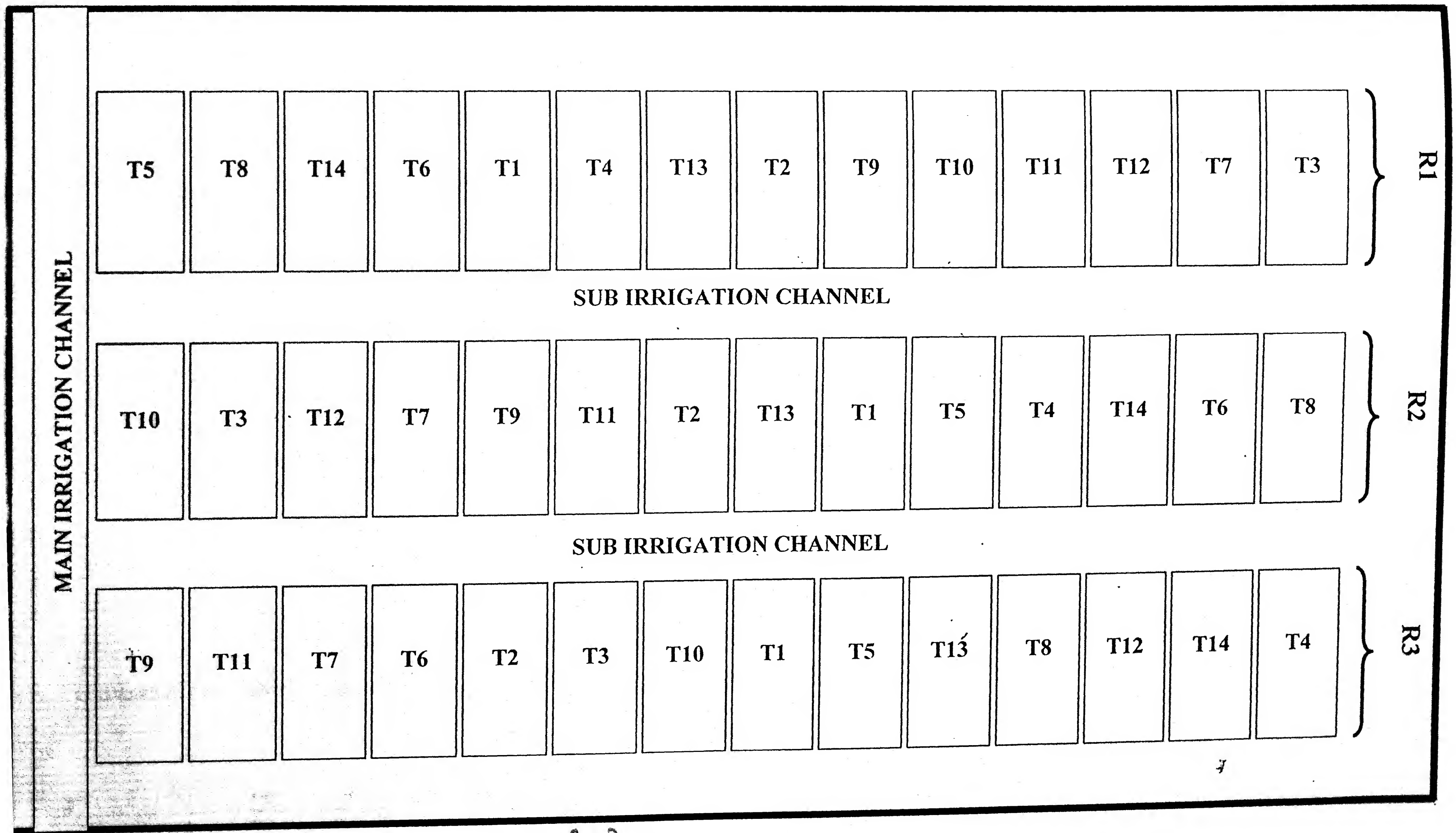


Fig. 3.3 Layout plan of experimental field

Table 3.6: Details of treatments and their symbols

S. No.		Detail of Treatments	Symbols
A.	**Within recommended dose**		
	1.	Sowing wheat without incorporation of rice residue and recommended NPK (Control)	**T_1**
	2.	Rice residue incorporation + recommended NPK at wheat sowing (Control)	**T_2**
	3.	15% of N at rice residue incorporation + rest at wheat sowing	**T_3**
	4.	30% of N at rice residue incorporation + rest at wheat sowing	**T_4**
	5.	15% of N + P at rice residue incorporation + rest at wheat sowing	**T_5**
	6.	30% of N + P at rice residue incorporation + rest at wheat sowing	**T_6**
	7.	15% of N + P + K at rice residue incorporation + rest at wheat sowing	**T_7**
	8.	30% of N + P + K at rice residue incorporation + rest at wheat sowing	**T_8**
B.	**Over and above recommended dose**		
	9.	Addition of 15% N + recommended NPK	**T_9**
	10.	Addition of 30% N + recommended NPK	**T_{10}**
	11.	Addition of 15% N +P + recommended NPK	**T_{11}**
	12.	Addition of 30% N +P + recommended NPK	**T_{12}**
	13.	Addition of 15% N +P+K + recommended NPK	**T_{13}**
	14.	Addition of 30% N +P+K + recommended NPK	**T_{14}**

3.8 Experimental details:

1.	Design	Randomized Block Design
2.	Number of replications	3
3.	Number of treatments	14
4.	Total number of plots	42
5.	Gross plot size	6.0 m x 5.0 m (5.0 - As crop sown with 22.5 cm row distance)
6.	Net plot size	5.0 m x 4.0 m (It should be 4.5 as 2 border row harvested from gross plot)
7.	Row distance	22.5 cm

3.9 Agronomic Practices:

3.9.1 Land Preparation:

Field was prepared and transplanted the rice seedling in plot for commercial rice cultivation along with recommended package of practices. In rice crop, a pre-harvest irrigation was applied. At proper moisture level rice crop was harvested and rice residue (30cm height) was incorporated as per the treatment (residue removed from T_1 plots). wheat was sown in lines at 22.5 cm apart. In rice residue removed and incorporated field conventional tillage practices were used, for the rice residue removed plot (T_1), the field was ploughed with desi plough and left of 7 days, thereafter, one pre-sowing irrigation was applied to the field. At the right tilth, 4 cross ploughing were done with desi plough. The planking was done invariably after each cross ploughing in order to get fine seed bed. Field preparation worked out for residue incorporated plot, the residue incorporated with the help of disc harrow and then all practices were same as residue removed treatment.

3.9.2 Fertilizer Application:

On the basis of plot size and treatment, doses of nitrogen, phosphorus and potassium through Urea, Single Super Phosphate and Murate of Potash were applied at all the treatment as basal dressing.

SP check

respectively

3.9.3 Sowing:

A common rate of seed (100 kg ha^{-1}) was sown in line at 22.5cm apart behind desi plough in all the treatments and planking was also done after sowing.

Name of variety and its characteristics required to be mention in this chapter.

3.9.4 Cultural operation:

All the recommended package of practices was followed for both the crop except residue management and nitrogen application in wheat.

3.9.5. Irrigation:

Irrigations were applied at all critical stages of wheat crop to each treatment.

3.9.6. Weed control:

mention rate and time of application

2, 4-D-Na salt + Isoproturon was applied for weed control in the field during the experimentation.

3.9.7. Harvesting:

The maturity was judged by visual observations when the leaves and stems turned yellow, then crop was harvested. The harvesting was done manually with the help of sickle. Before harvesting of net plot area two border rows length wise and 0.5m area width-wise from both the sides of each plot were harvested and kept aside to avoid the error.

The harvesting of the net plot was done separately and the harvested material of each plot was carefully bundled, tagged and brought to threshing floor separately.

3.9.8: Threshing, winnowing and recording of yield:

The sun-dried weight of total biological produce of each net plot was recorded before threshing. Threshing was done with thresher and grain yield of each net plot was separated by winnowing, recorded in kg and finally expressed in q ha^{-1}. To obtain straw yield, the grain yield was deducted from total biological produce.

3.10 Observation and sampling procedure:

2 line from both side

By leaving 1.0 m length-wise and 1.0 m area width wise from both the side of each plot, the inner area was treated as the net plot. At regular intervals sample observations were recorded from the net plot area.

3.11 Observations recorded:

3.11.1 Growth characters

(i) Plant height:

Five plants were selected randomly in each plot and tagged for measuring height at different intervals. Height was measured at 30th, 60th, 90thdays after sowing and at harvest stage of crop with the help of metre scale from soil surface to the tip of the top most leaf before heading and from soil surface to the base of ear after heading.

(ii) Number of green leaves plant^{-1}:

Number of green leaves per plant were recorded randomly from three tagged places for number of green leaves per plant in each net

plot at 30, 60th, 90th days after sowing stages of the crop growth and averaged out to number of green leaves per plant.

(iii) Dry matter accumulation:

Plant samples were taken randomly of 25cm row length at three places from border rows adjacent to net plot. The selected samples were dried in oven at 60°C till the constant weight received. The weight of dried samples was recorded in gram and finally expressed in gram per metre square area at different intervals. Pl correct

In chapter-4 data presented as running metre

(iv) Number of tillers plant^{-1}:

Number of tillers were recorded randomly from three tagged places for number of tillers per plant in each net plot at 30, 60th, 90th days after sowing and at harvest stages of the crop growth and averaged out to number of tillers per plant.

In chapter-4 data presented as running metre instead of per plant. Pl correct which one is true.

3.11.2 Yield attributes:

(i) Number of effective tillers:

Number of effective tillers was counted from three randomly tagged places in each net plot per square metre area basis. The mean values were expressed as number of effective tillers ~~ears~~ per square metre.

(ii) Length of ear head:

Spike length was measured in cm of five randomly selected spikes in each plot from lower scare of the spike to its tip and averaged out for one spike length.

Days take to 75% heading and days taken to maturity of wheat are not illustrated in this chapter. It should be incorporated.

(iii) Number of spikelets per spike:

spike/earhead

The total number of fertile spikelets of five selected ear from each plot were counted and averaged to get the number of spikelets per spike.

(iv) Number of sterile spikelets per spike:

spike/earhead

The total number of sterile spikelets of five selected ear from each plot were counted and averaged to get the number of sterile spikelets per spike.

(v) Number of grains per spike:

Total number of grains were counted in five randomly selected spikes in each plot and their mean values were expressed as number of grains per spike.

(vi) 1000-grain weight:

The samples comprising to 1000-grains were drawn irrespective of size and shape from the grain produce of each plot and weight to record the test weight in grams.

3.11.3 Yield

(i) Grain yield:

The grain yield was recorded in kg $plot^{-1}$ separately from each net plot after threshing and winnowing. The figures were finally converted into q ha^{-1}.

(ii) Straw yield:

Straw yield was calculated by subtracting the grain yield from the total biological produce of the net plot area and finally expressed in terms of q ha^{-1}.

(iii) Harvest Index:

The recovery of grain in total produces was considered as harvest index and was expressed in percentage. It was calculated by using the following formula.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (q ha}^{-1}\text{)}}{\text{Biological yield (q ha}^{-1}\text{)}} \times 100$$

3.11.4 Chemical studies of plant:

The grain and straw samples collected at the time of harvest were dried in the oven and ground by sample grinder. After grinding, the samples were analysed chemically for nitrogen content by micro Kjeldahl's method, as given by (Jackson, 1973).

$$\text{Uptake of nutrient (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)}}{100} \times \text{yield (q ha}^{-1}\text{)}$$

3.11.5 Chemical analysis of soil:

The soil samples collected at the time of before sowing and after harvesting of wheat were analysed chemically for organic carbon and nitrogen content.

3.12 Economics:

Cost of cultivation was worked out on one hectare basis. Common cost of cultivation as well as treatment wise cost of cultivation was worked out on the prevailing rates during experimentation. The net income was calculated by subtracting total cost of cultivation from the gross income obtained from grain and straw yield. Net income per rupee investment was calculated by the following formula:

$$\text{Net income per rupee investment} = \frac{\text{Net income (Rs ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs ha}^{-1}\text{)}}$$

3.13 Statistical analysis:

The data collected of the experiments were subjected to statistical analysis with the procedure for randomized block design as suggested by Gomez and Gomez (1984). The Table for analysis of variance is given as under:

Table 3.7 Analysis of variance table

Source of variation	d.f.	SS	MSS	F value	
				Cal.	Tab at 5%
Replication	2				
Treatments	13				
Error	26				
Total	41				

If the variance ratio were significant at 5% level of significant, SEm± and C.D. were calculated with the help of following formula:

$$\text{S.E.m}\pm = \sqrt{\frac{\text{Error mean sum of square}}{r}}$$

Where,

S.E.m± = Standard error of mean

r = Number of observations averaged

Critical difference (C.D.) or least significant difference (LSD)

It was calculated by the following formulae-

CD = S.E.m± x 1.414 x t value at 5% level of significance for error degree of freedom.

Coefficient of variance (CV) %

It was calculated by following formulae-

$$CV\,\% = \sqrt{\frac{\text{Variance of error}}{\text{General mean}}} \times 100$$

PHOTOGRAPH


T13


T14

Chapter four

EXPERIMENTAL FINDINGS

Chapter-IV

EXPERIMENTAL FINDINGS

The results of present investigation entitled **"Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice – wheat sequence"** obtained on plant growth, yield, yield contributing characters; quality, soil studies and economic analysis have been presented in tables and illustrated graphically wherever necessary. Data on the different characters under study were put to statistical test of significance and results have been logically interpreted as under. The analyses of variance for various characters have been given in Appendix.

4.1 Growth characters:

4.1.1 Initial plant population:

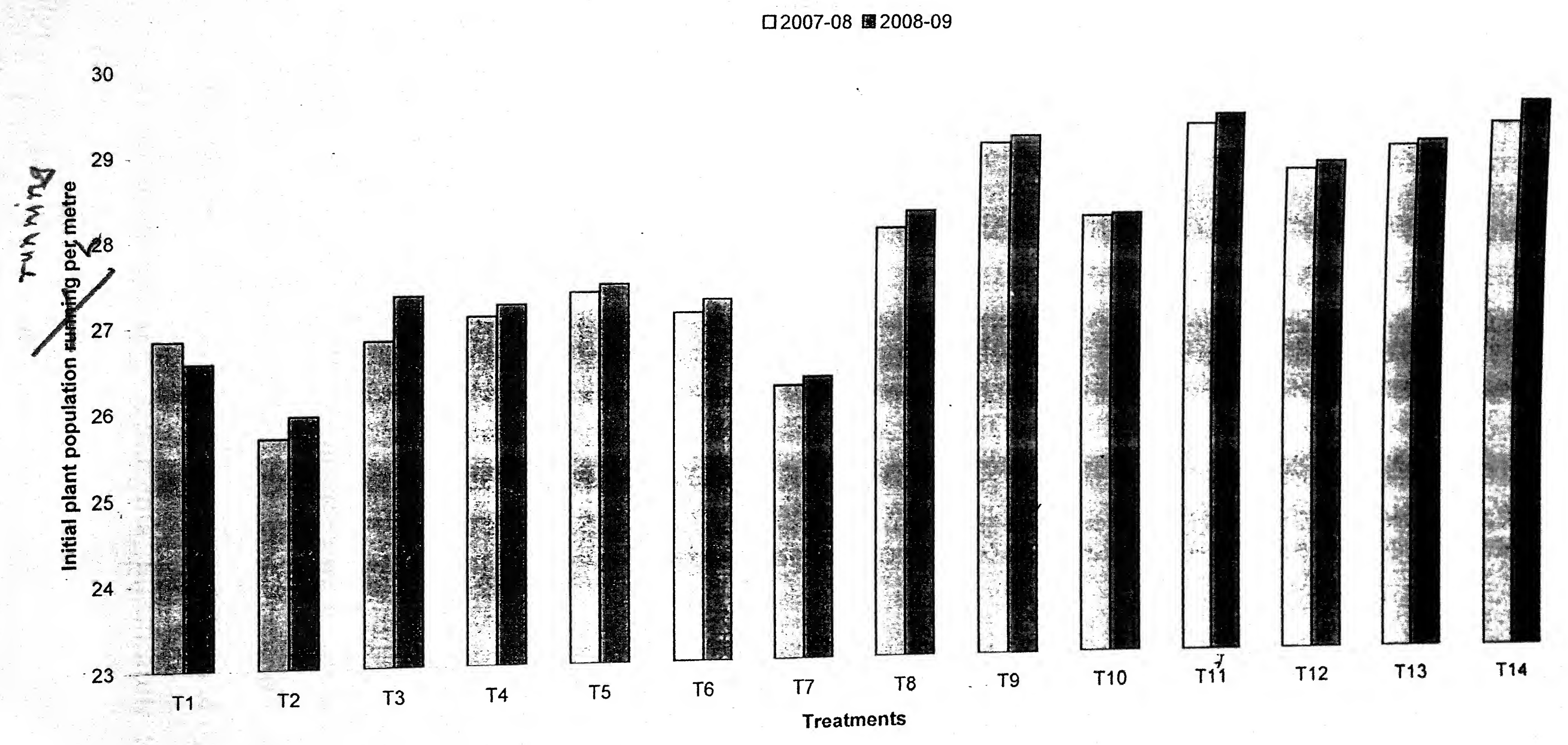
The data pertaining to initial plant population running metre^{-1} as influenced by various treatments have been presented in Table 4.1 and depicted in Fig. 4.1.

It is clear from the data that various rice residue and nutrient management systems did not influence the initial plant population significantly during both the years. However, the maximum plant population per metre row length (29.36 and 29.62) was recorded under the effect of 30% additional NPK + recommended NPK (T_{14}) during 2007-08 and 2008-09, respectively.

Table 4.1: Effect of varying rice residue management practices on initial plant population per running metre of wheat

Treatments	Initial plant population running metre^{-1}	
	2007-08	**2008-09**
T_1	26.84	26.57
T_2	25.69	25.95
T_3	26.82	27.35
T_4	27.10	27.24
T_5	27.38	27.47
T_6	27.12	27.28
T_7	26.23	26.33
T_8	28.11	28.31
T_9	29.12	29.21
T_{10}	28.23	28.26
T_{11}	29.35	29.47
T_{12}	28.79	28.88
T_{13}	29.08	29.14
T_{14}	29.36	29.62
SEm±	0.87	0.95
CD at 5%	N.S.	N.S.

Figure 4.1: Effect of varying rice residue management practices on initial plant population per running metre of wheat



4.1.2 Plant height:

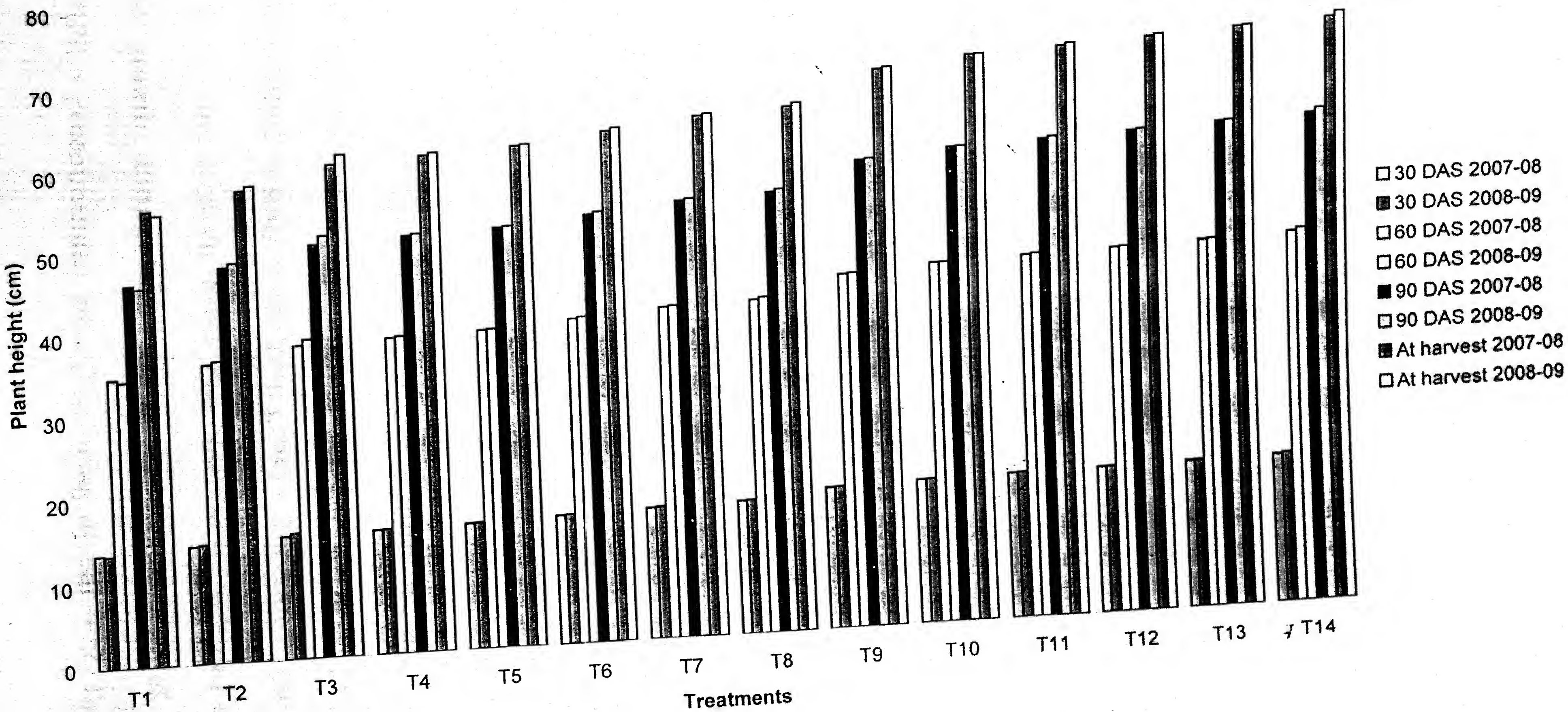
Plant height was measured at 4 stages of crop growth (at 30th, 60th, 90th day and harvest stages). The age-height curves (Fig. 4.2) exhibit that the plant height influenced significantly with different rice residue and nutrient management treatments and the maximum plant height was recorded by application of 30% additional NPK with recommended NPK at all the growth stages during both the years of study. Further, it is clear from the curves that the plant height increased consistently with advancement in age of crop plant and the maximum was recorded at harvest stage of crop growth under the effects of all the treatments. The maximum increase in plant height was noticed between 30th and 60th day stages. These statements are true for both the years of field experimentation.

The data given in Table 4.2 clearly indicate that shoot elongation rate continued to increase with the age of the crop and a marked increase in plant height was observed at 90th day stage of the crop growth. Thereafter, the rate of increase in shoot height was nominal till harvest stage of the crop during both the years. Application of 30% additional NPK (T_{14}) being at par with application of 15% additional N + recommended NPK (T_9) at all the growth stages but produced significantly taller plant as compared with control (T_1- sowing of wheat without incorporation of rice residue and recommended NPK) and rest of the within recommended doses of N, P and K and rice residue incorporation treatments. Significantly the

Table 4.2: Effect of varying rice residue management practices on plant height (cm) at various growth stages of wheat

Treatments	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	13.83	13.69	35.00	34.65	46.42	45.95	55.52	54.97
T_2	14.36	14.50	36.34	36.71	48.20	48.69	57.66	58.23
T_3	15.07	15.37	38.14	38.90	50.58	51.60	60.50	61.71
T_4	15.25	15.32	38.59	38.78	51.18	51.43	61.21	61.52
T_5	15.43	15.47	39.04	39.15	51.77	51.93	61.93	62.11
T_6	15.78	15.87	39.93	40.17	52.96	53.28	63.35	63.73
T_7	16.13	16.20	40.83	41.00	54.15	54.37	64.77	65.03
T_8	16.31	16.43	41.28	41.57	54.75	55.13	65.49	65.94
T_9	17.38	17.43	43.97	44.10	58.32	58.49	69.76	69.97
T_{10}	17.73	17.75	44.87	44.91	59.51	59.57	71.18	71.25
T_{11}	17.91	17.98	45.32	45.50	60.11	60.35	71.89	72.18
T_{12}	18.08	18.14	45.77	45.90	60.70	60.88	72.60	72.82
T_{13}	18.26	18.30	46.22	46.31	61.30	61.42	73.32	73.46
T_{14}	18.44	18.61	46.66	47.08	61.89	62.45	74.03	74.69
SEm±	0.52	0.57	1.32	1.45	1.75	1.92	2.09	2.30
CD at 5%	1.51	1.66	3.83	4.21	5.07	5.58	6.07	6.68

Figure 4.2: Effect of varying rice residue management practices on plant height (cm) at various growth stages of wheat



lowest plant height was noted with T_1 (sowing of wheat without incorporation of rice residue and recommended NPK) in both the years.

4.1.3 Number of green leaves:

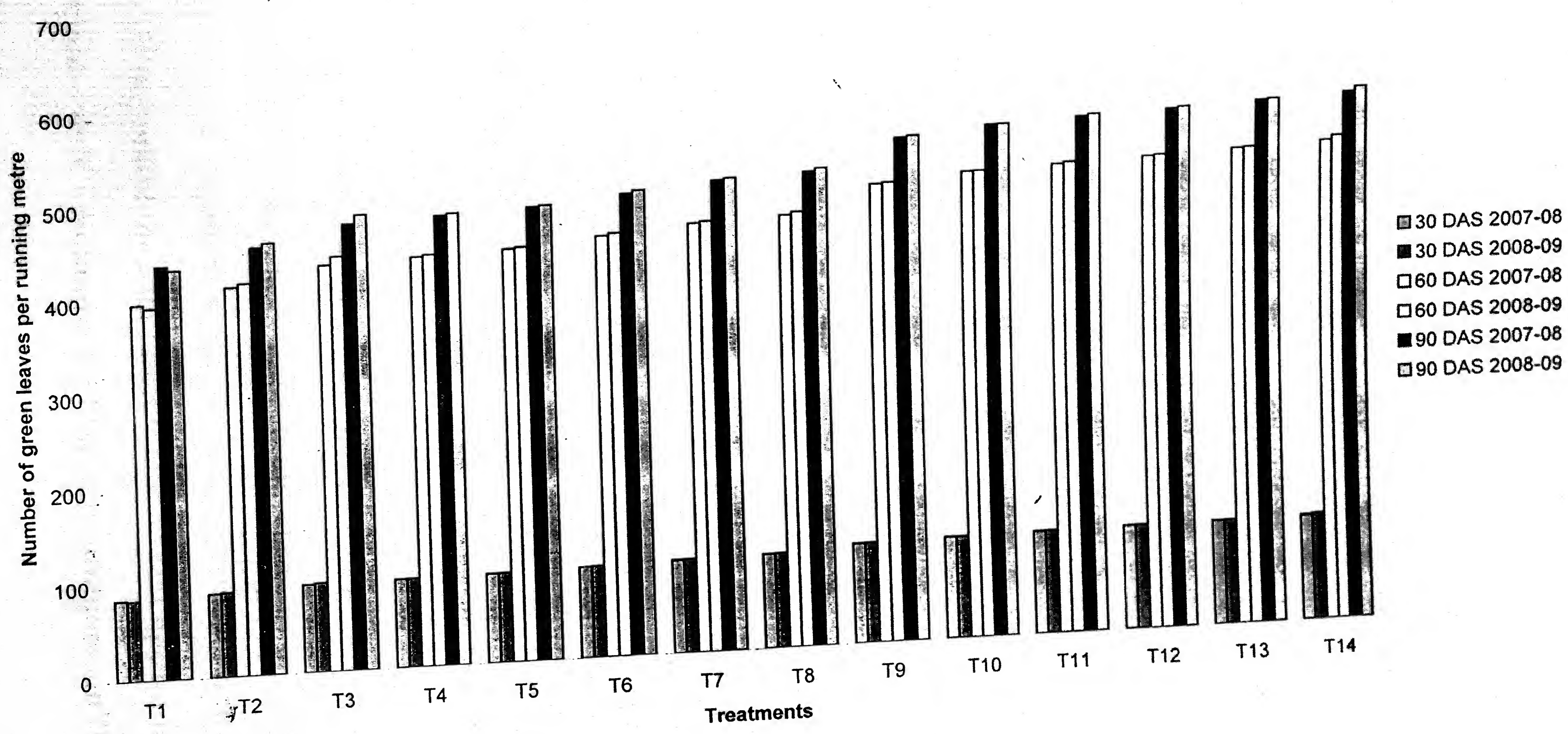
Number of green leaves was counted at 3 stages of crop growth (at 30th, 60th and 90th day stages). The number of green leaves per running metre as influenced by different rice residue management practices (Fig. 4.3) exhibit that the number of green leaves influenced significantly with different rice residue and nutrient management practices and the maximum was recorded by application of 30% additional NPK + recommended NPK at all the growth stages during both the years of study. Further, it is clear from the graph that the number of green leaves increased consistently with advancement in age of crop plant and the maximum was recorded at 90th day of crop growth under the effects of all the treatments. The maximum increase in number of green leaves per running metre was noticed between 30th and 60th day stages. These statements are true for both the years of field experimentation.

The data given in Table 4.3 indicate that number of green leaves continued to increase with the age of the crop and a marked increase was observed at 60th day stage of the crop growth. Thereafter, the rate of increase in number of green leaves was nominal till 90th day stage of the crop growth during both the years. Application of 30% additional NPK + recommended NPK (T_{14}) being at par with T_9, T_{10},

Table 4.3: Effect of varying rice residue management practices on number of green leaves per running metre at various growth stages of wheat

Treatments	Number of green leaves per running metre					
	30 DAS		60 DAS		90 DAS	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	85.86	85.00	398.85	394.86	439.23	434.84
T_2	89.16	90.06	414.19	418.33	456.13	460.69
T_3	93.57	95.44	434.64	443.33	478.65	488.23
T_4	94.67	95.14	439.75	441.95	484.28	486.70
T_5	95.77	96.06	444.87	446.20	489.91	491.38
T_6	97.97	98.56	455.09	457.82	501.18	504.18
T_7	100.17	100.57	465.32	467.18	512.44	514.49
T_8	101.27	101.98	470.43	473.73	518.07	521.70
T_9	107.88	108.20	501.11	502.62	551.86	553.51
T_{10}	110.08	110.19	511.34	511.85	563.12	563.68
T_{11}	111.18	111.63	516.45	518.52	568.75	571.03
T_{12}	112.28	112.62	521.57	523.13	574.38	576.11
T_{13}	113.38	113.61	526.68	527.73	580.01	581.17
T_{14}	114.48	115.51	531.79	536.58	585.64	590.92
SEm±	3.23	3.55	14.99	25.92	16.51	18.17
CD at 5%	9.38	10.33	43.59	75.34	48.01	52.83

Figure 4.3: Effect of varying rice residue management practices on number of green leaves per running metre at various growth stages of wheat



T_{11}, T_{12} and T_{13} (application of 15 and 30% additional N, N and P as well as 15% additional NPK) at all the growth stages but produced significantly higher number of green leaves per running metre as compared with T_1 (sowing of wheat without incorporation of rice residue and recommended NPK) and rest of the within recommended doses of N, P and K and rice residue incorporation treatments. Significantly the lowest number of green leaves per running metre was noted with T_1 (sowing of wheat without incorporation of rice residue and recommended NPK) in both the years.

4.1.4 Dry matter accumulation:

The data pertaining to dry matter accumulation per running metre at various stages of the crop growth have been presented in Table 4.4 and Fig. 4.4.

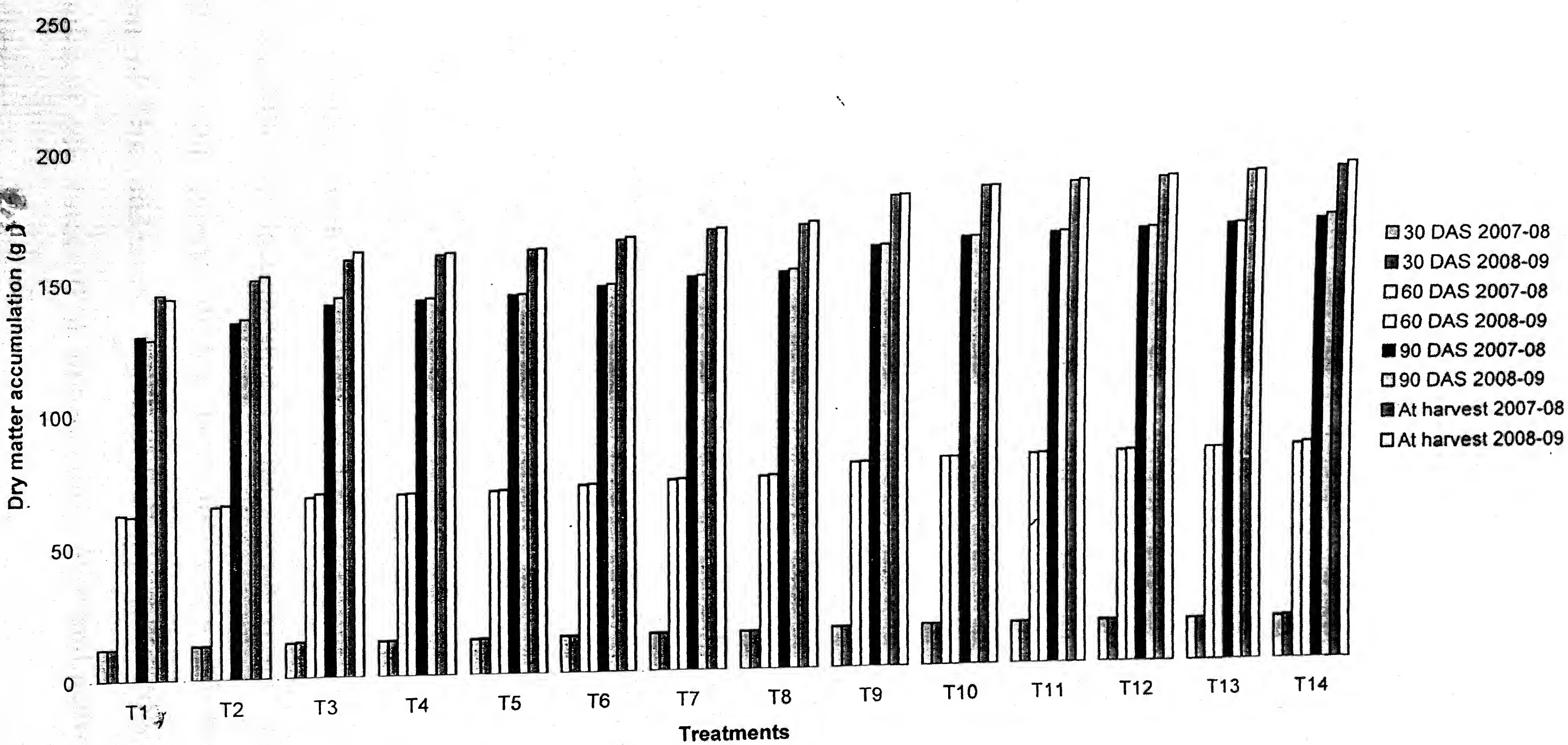
The data on dry matter accumulation pattern as affected by different rice residue and nutrient management practices reveal that in general the dry matter accumulation increased with the advancement of the crop age. The rate of increase in dry matter accumulation was faster upto 90th day stage after which it showed slow rate till maturity.

It is evident from the data that different rice residue and nutrient management practices had significant effect on dry matter production at all the successive stages of the crop growth during both the years. The perusal of the data obviously revealed that application of 30% additional N+P+K + recommended NPK with incorporation of rice

Table 4.4: Effect of varying rice residue management practices on dry matter accumulation per ~~running~~ metre at various growth stages of wheat

Treatments	Dry matter accumulation (g)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	12.43	12.31	62.54	61.91	130.10	128.80	145.91	144.45
T_2	12.91	13.04	64.95	65.60	135.10	136.45	151.52	153.03
T_3	13.55	13.82	68.15	69.52	141.77	144.61	159.00	162.18
T_4	13.71	13.78	68.95	69.30	143.44	144.16	160.87	161.68
T_5	13.87	13.91	69.76	69.97	145.11	145.54	162.74	163.23
T_6	14.19	14.27	71.36	71.79	148.44	149.33	166.48	167.48
T_7	14.51	14.56	72.96	73.26	151.78	152.39	170.22	170.91
T_8	14.66	14.77	73.77	74.28	153.45	154.52	172.10	173.30
T_9	15.62	15.67	78.58	78.81	163.45	163.94	183.32	183.87
T_{10}	15.94	15.96	80.18	80.26	166.79	166.96	187.06	187.25
T_{11}	16.10	16.16	80.98	81.31	168.46	169.13	188.93	189.69
T_{12}	16.26	16.31	81.78	82.03	170.13	170.64	190.80	191.37
T_{13}	16.42	16.45	82.59	82.75	171.79	172.14	192.67	193.06
T_{14}	16.58	16.73	83.39	84.14	173.46	175.02	194.54	196.29
SEm$\pm$	0.47	0.81	2.35	2.59	8.42	5.38	5.60	8.08
CD at 5%	1.36	2.35	6.84	7.52	24.47	15.65	16.28	23.48

Figure 4.4: Effect of varying rice residue management practices on dry matter accumulation per running metre at various growth stages of wheat



residue (T_{14}) had significant effect on dry matter accumulation at all the successive stages of the crop growth over control during both the years. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) recorded statistically at par with rest of the over and above recommended dose treatments but found significantly higher over all the within recommended doses of NPK at all the successive growth stages and both the years of study.

4.1.5 Number of tillers:

The data on number of tillers running metre^{-1} at successive stages of the crop growth as affected by various treatments have been presented in Table 4.5 and depicted in Fig. 4.5.

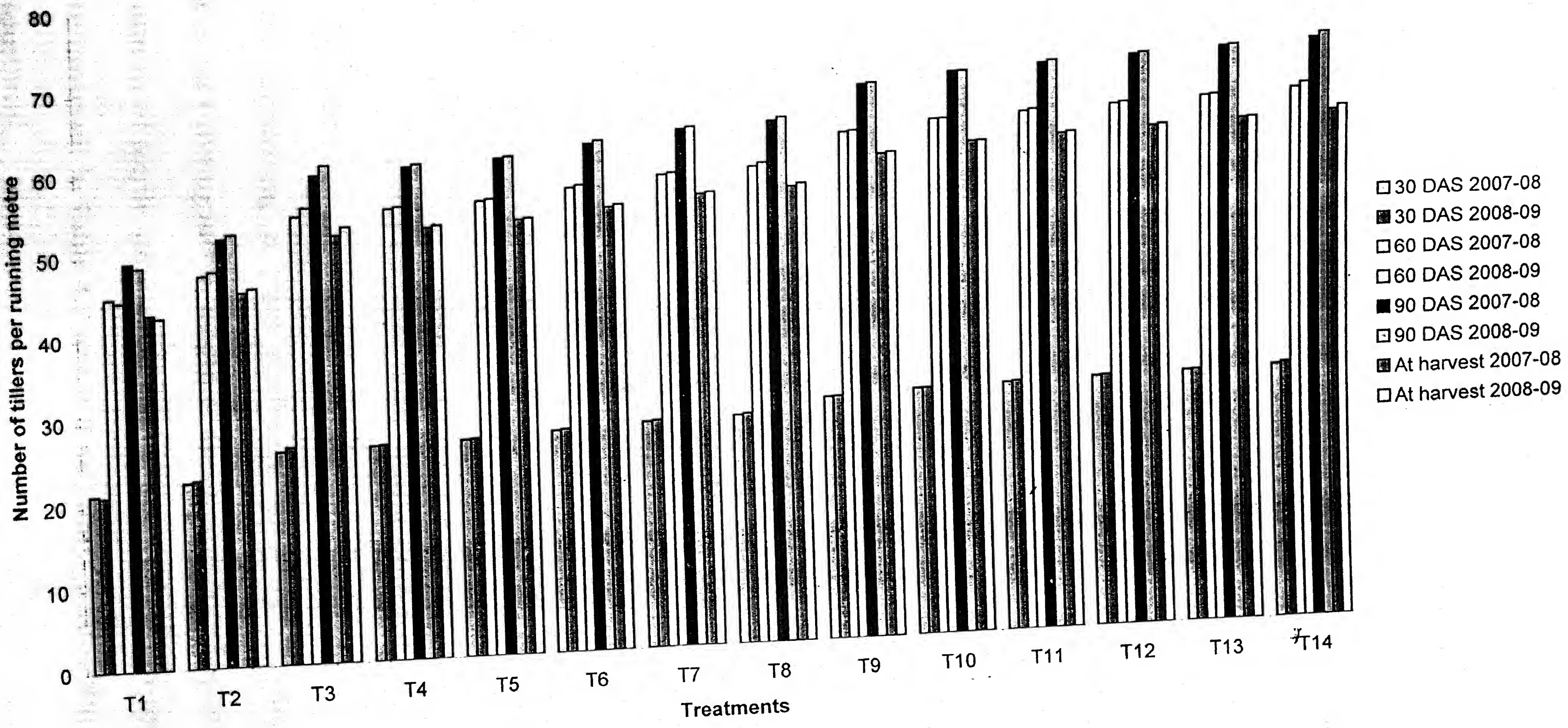
The data given in Table 4.5, indicate that in general, the trend of increase in number of tillers was observed upto 90th day stage thereafter it declined slightly till harvest. The magnitude of increase in number of tillers running metre^{-1} was highest between 30th to 60th day stages.

The rice residue and nutrient management system affect the number of tillers running metre^{-1} significantly. The differences were perceptible at later stages of the crop growth. The highest number of tillers were recorded with application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) at all the stages of the crop growth during both the years followed by application of 15% additional N+P+K + recommended NPK with incorporation of rice residue (T_{13}). Application of over and above dose

Table 4.5: Effect of varying rice residue management practices on number of tillers per running metre at various growth stages of wheat

Treatments	Number of tillers running metre^{-1}							
	30 DAS		60 DAS		90 DAS		At harvest	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	21.22	21.01	44.96	44.51	49.22	48.73	42.93	42.50
T_2	22.44	22.66	47.53	48.01	52.04	52.56	45.38	45.84
T_3	25.77	26.29	54.60	55.69	59.77	60.97	52.13	53.17
T_4	26.08	26.21	55.24	55.51	60.48	60.78	52.74	53.01
T_5	26.38	26.46	55.88	56.05	61.18	61.36	53.36	53.52
T_6	26.98	27.15	57.16	57.51	62.58	62.96	54.58	54.91
T_7	27.59	27.70	58.45	58.68	63.99	64.25	55.81	56.03
T_8	27.89	28.09	59.09	59.51	64.69	65.15	56.42	56.82
T_9	29.71	29.80	62.95	63.13	68.91	69.12	60.10	60.28
T_{10}	30.32	30.35	64.23	64.29	70.32	70.39	61.33	61.39
T_{11}	30.62	30.75	64.87	65.13	71.02	71.31	61.94	62.19
T_{12}	30.93	31.02	65.51	65.71	71.73	71.94	62.56	62.74
T_{13}	31.23	31.29	66.16	66.29	72.43	72.57	63.17	63.30
T_{14}	31.53	31.82	66.80	67.40	73.13	73.79	63.78	64.36
SEm$\pm$	0.88	0.97	1.87	2.06	2.05	2.26	1.79	1.97
CD at 5%	2.57	2.83	5.44	6.00	5.96	6.56	5.20	5.73

Figure 4.5: Effect of varying rice residue management practices on number of tillers per running metre at various growth stages of wheat



of nutrient recorded with significantly higher number of tillers per running metre over control and within recommended dose. While, minimum number of tillers running metre^{-1} was obtained with control which statistically at par with rice residue incorporation + recommended NPK.

4.1.6 Days taken to 75 per cent heading:

The data presented in Table 4.6 and depicted in Fig. 4.6 reveal that the maximum days taken to 75 per cent heading were recorded with application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}), while the lowest with T_1 (sowing of wheat without incorporation of rice residue and recommended NPK). However, the differences were non-significant during both the years.

In table diff. is indicated as significant.

4.1.7 Days taken to maturity:

The data presented in Table 4.6 and depicted in Fig. 4.6 reveal that the maximum days taken to maturity were recorded with application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}), while the lowest with T_1 (sowing of wheat without incorporation of rice residue and recommended NPK). However, the differences were non-significant during both the years.

In table as CD written it indicate significant result.

4.2 Yield attributes:

The data pertaining to yield attributes such as number of effective tillers per running metre, length of spike, number of spikelets per spike, number of sterile spikelets per spike and 1000-grain weight have been summarized in Table 4.7 and 4.8 and illustrated in Fig. 4.7 and 4.8, respectively.

Table 4.6: Effect of varying rice residue management practices on days take to 75% heading and days taken to maturity of wheat

Treatments	Days taken to 75% heading		Days taken to maturity	
	2007-08	2008-09	2007-08	2008-09
T_1	77.80	77.02	122.04	120.82
T_2	76.95	77.72	120.71	121.92
T_3	78.64	80.21	123.36	125.83
T_4	81.18	81.58	127.34	127.98
T_5	79.49	79.72	124.69	125.07
T_6	82.87	83.37	130.00	130.78
T_7	80.33	80.65	126.02	126.52
T_8	83.71	84.30	131.32	132.24
T_9	82.02	82.27	128.67	129.06
T_{10}	84.56	84.64	132.65	132.78
T_{11}	83.71	84.05	131.32	131.85
T_{12}	87.10	87.36	136.63	137.04
T_{13}	84.56	84.73	132.65	132.92
T_{14}	87.94	88.73	137.96	139.20
SEm±	2.59	2.81	4.06	4.41
CD at 5%	7.52	8.17	11.80	12.82

Figure 4.6: Effect of varying rice residue management practices on days take to 75% heading and days taken to maturity of wheat

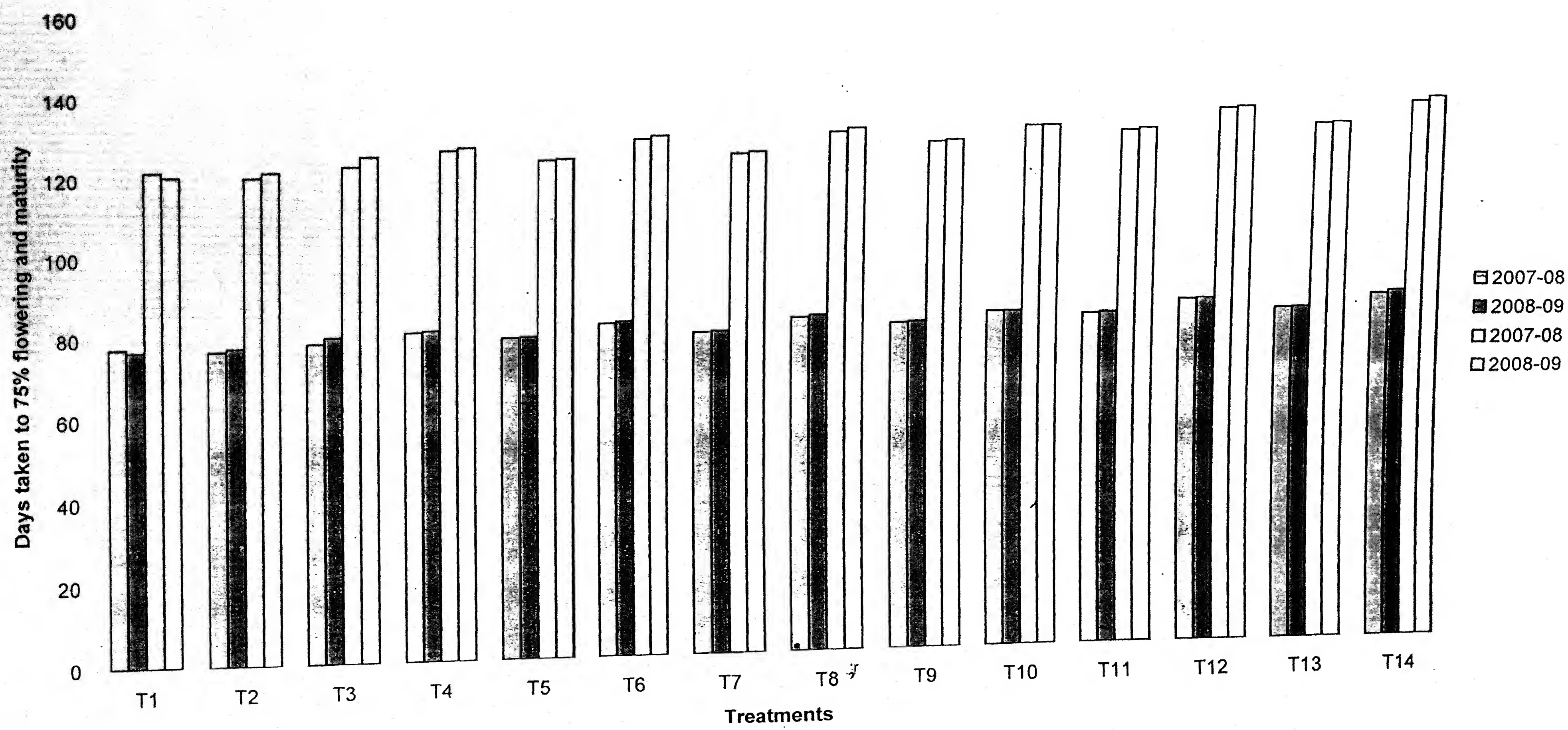
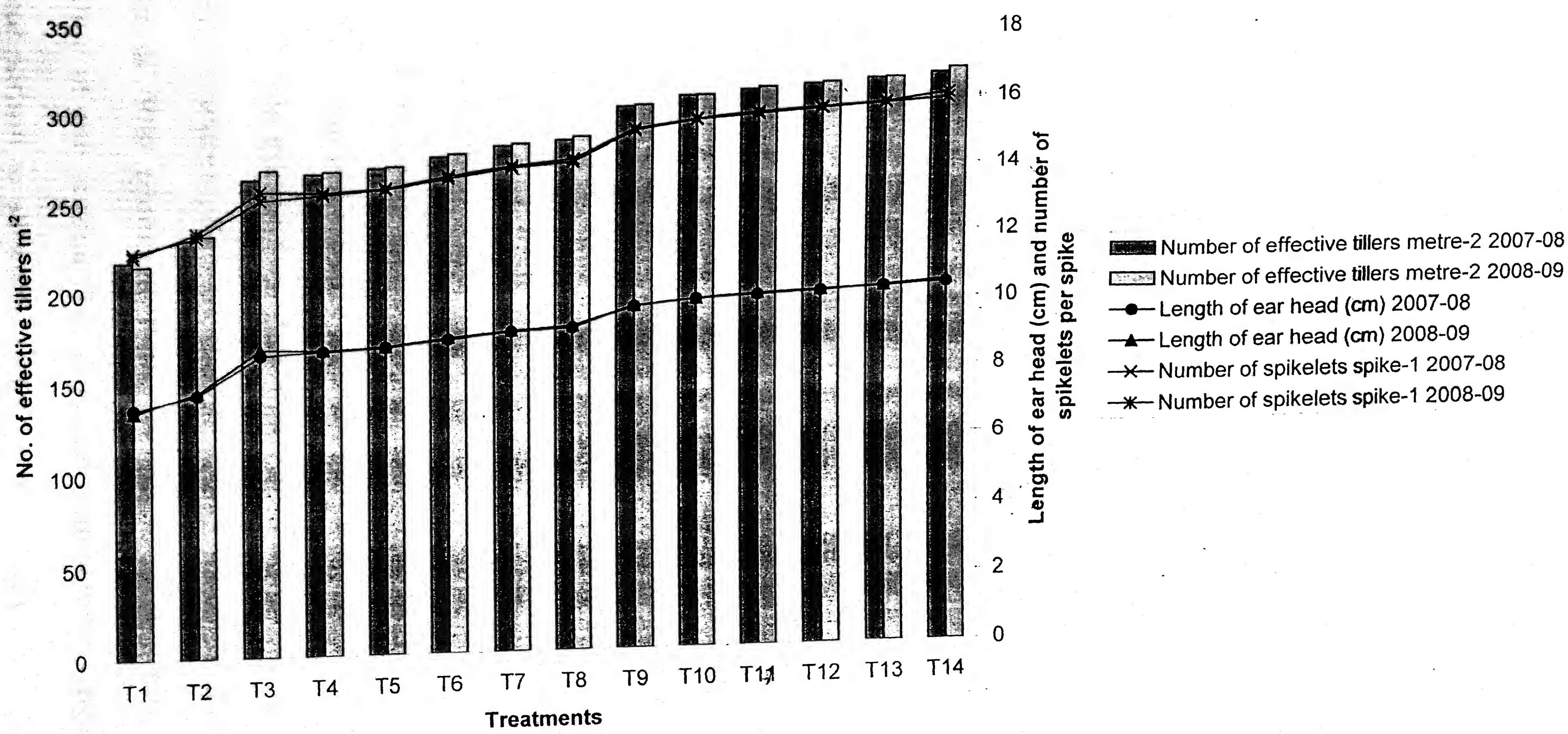


Table 4.7: Effect of varying rice residue management practices on number of effective tillers metre^{-2}, length of ear head and number of spikelets spike^{-1} in wheat

Treatments	Number of effective tillers metre^{-2}		Length of ear head (cm)		Number of spikelets spike^{-1}		Number of sterile spikelets spike^{-1}	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	218.05	215.87	7.01	6.94	11.48	11.37	2.46	2.44
T_2	230.51	232.82	7.41	7.49	11.94	12.06	2.42	2.44
T_3	264.78	270.07	8.52	8.69	13.01	13.27	2.38	2.42
T_4	267.89	269.23	8.62	8.66	13.17	13.23	2.33	2.34
T_5	271.01	271.82	8.72	8.74	13.32	13.36	2.29	2.30
T_6	277.24	278.90	8.92	8.97	13.63	13.71	2.25	2.26
T_7	283.47	284.60	9.12	9.15	13.93	13.99	2.20	2.21
T_8	286.58	288.59	9.22	9.28	14.09	14.18	2.16	2.18
T_9	305.27	306.19	9.82	9.85	15.00	15.05	2.10	2.10
T_{10}	311.50	311.81	10.02	10.03	15.31	15.33	2.10	2.10
T_{11}	314.62	315.87	10.12	10.16	15.46	15.52	2.01	2.02
T_{12}	317.73	318.68	10.22	10.25	15.62	15.66	1.95	1.95
T_{13}	320.85	321.49	10.32	10.34	15.77	15.80	1.90	1.91
T_{14}	323.96	326.88	10.42	10.51	15.92	16.07	1.86	1.88
SEm$\pm$	9.08	10.00	0.29	0.32	0.45	0.49	0.07	0.07
CD at 5%	26.39	29.08	0.85	0.94	11.48	1.43	0.20	0.21

Figure 4.7: Effect of varying rice residue management practices on number of effective tillers metre^{-2}, length of ear head and number of spikelets spike^{-1} in wheat



4.2.1 Number of effective tillers:

The data pertaining to number of effective tillers per running metre as affected by varying rice residue and nutrient management practices are presented in Table 4.7 and Fig. 4.7. It is evident from data that rice residue and nutrient management practices affect the number of effective tillers per running metre significantly. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) produced significantly more number of effective tillers in comparison to all within recommended doses (T_1 to T_8) but statistically at par with all over and above recommended doses (T_9 to T_{13}). The differences among the treatments [illegible] over and above recommended doses were non-significant. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) recorded more number of effective tillers (323.96 and 326.88) exhibited an increase of 48.57 and 51.42 per cent in year 2007-08 and 2008-09 over those recorded by T_1 (sowing of wheat without incorporation of rice residue and recommended NPK), respectively.

4.2.2 Length of ear head (cm):

The data pertaining to length of spike as affected by varying rice residue and nutrient management practices are presented in Table 4.7 and Fig. 4.7. It is evident from data that rice residue and nutrient management practices affect the length of ear head significantly. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) produced significantly longer ear head in comparison to all within recommended doses (T_1 to T_8) but

statistically at par with all over and above recommended doses (T_9 to T_{13}). The differences among over and above recommended doses were non-significant. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) measured with more length of ear head (10.42 and 10.51) exhibited an increase of 48.64 and 51.44 per cent in year 2007-08 and 2008-09 over those recorded by T_1 (sowing of wheat without incorporation of rice residue and recommended NPK), respectively.

4.2.3 Number of spikelets spike^{-1}:

The data pertaining number of spikelets spike^{-1} as affected by varying rice residue and nutrient management practices are presented in Table 4.7 and Fig. 4.7. It is evident from data that rice residue and nutrient management practices affect the number of spikelets spike^{-1} significantly. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) produced significantly more number of spikelets spike^{-1} in comparison to all within recommended doses (T_1 to T_8) but statistically at par with all over and above recommended doses (T_9 to T_{13}). The differences among over and above recommended doses were non-significant. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) recorded with more number of spikelets spike^{-1} (15.92 and 16.07) exhibited an increase of 38.68 and 41.34 per cent in year 2007-08 and 2008-09 over those recorded by T_1 (sowing of wheat without incorporation of rice residue and recommended NPK), respectively.

4.2.4 Number of sterile spikelets spike^{-1}:

An examination of Table 4.7 and Fig. 4.7 obviously reveals that the highest number of sterile spikelets per spike were obtained with control (T_1- sowing of wheat without incorporation of rice residue and recommended NPK), which was at par with other within recommended doses (T_2 to T_5) during both the years. Different rice residue and nutrient management practices influenced the number of sterile spikelets spike^{-1} significantly. The highest number of sterile spikelets spike^{-1} (2.46 and 2.44) were noted with control (T_1- sowing of wheat without incorporation of rice residue and recommended NPK) during both the years, respectively, which were 24.39 and 22.95 per cent higher in 2007-08 and 2008-09 than that obtained with application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}), respectively.

4.2.5 Test weight (1000-grain weight):

The data pertaining to test weight as influenced by various treatments are presented in Table 4.8 and illustrated in Fig. 4.8 reveal that significantly higher test weight were recorded with application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) (41.97 and 42.35 g) followed by application of 15% additional N+P+K + recommended NPK with incorporation of rice residue (T_{13}), during both the years, respectively. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) produced higher test weight and registered an increase of 38.65 and 41.31 per cent in 2007-08 and 2008-09 over that of control

(T_1- sowing of wheat without incorporation of rice residue and recommended NPK), respectively.

4.3 Yield

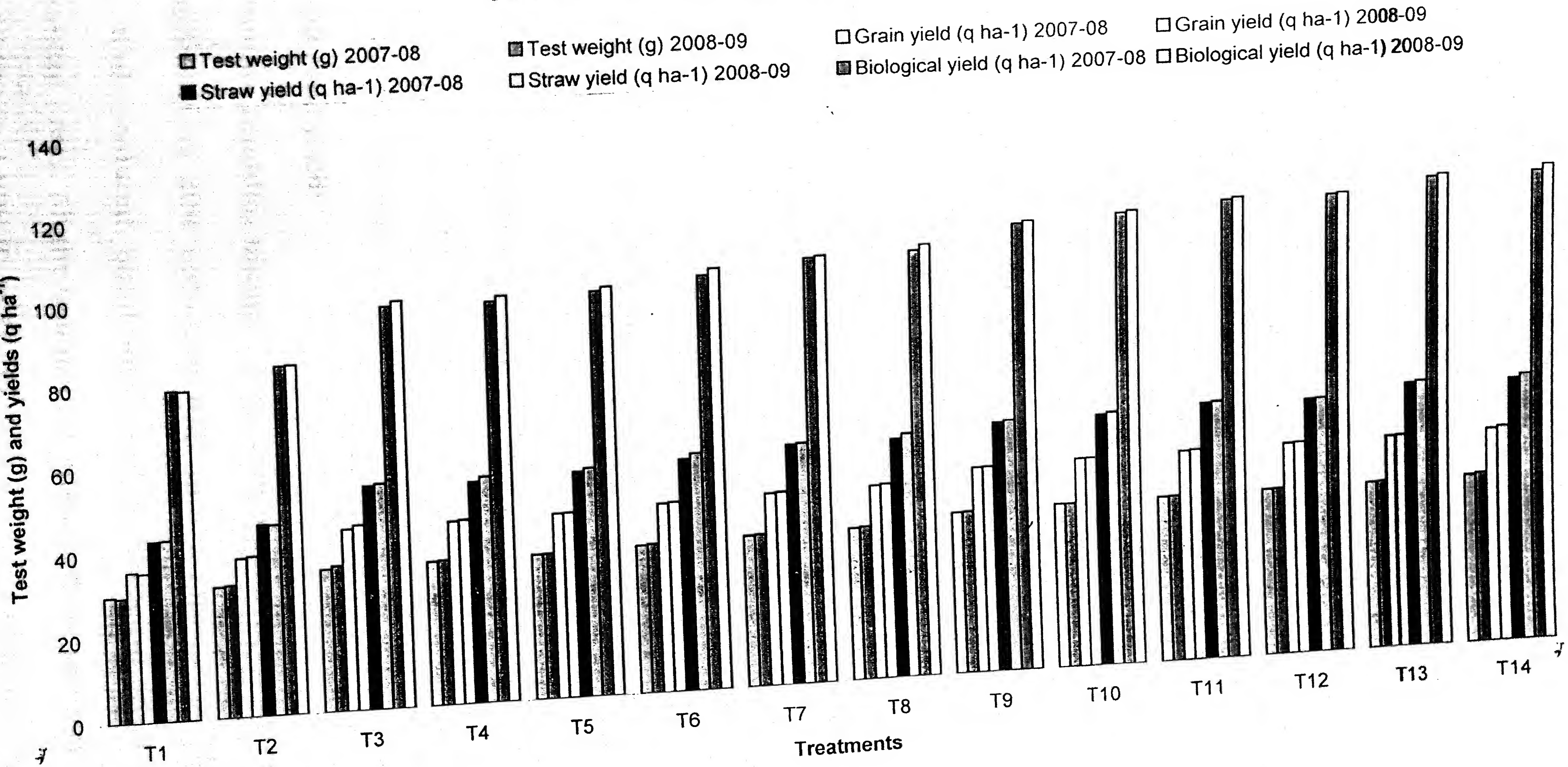
4.3.1 Grain yield:

The data pertaining to grain yield, straw yield and biological yield have been presented in Table 4.8 and depicted in Fig. 4.8. The data regarding grain yield presented in Table 4.8 reveal that rice residue incorporation (T_2) proved superiority over residue removed (T_1) though, the differences were significant when a part of 15 or 30% of the recommended dose of fertilizer as an additional dose particularly N was applied at the time of residue incorporation. Maximum grain yield (53.48 and 53.96 q ha^{-1}) was obtained with application of 30% additional NPK at incorporation of rice residue (T_{14}) being at par with T_9, T_{10}, T_{11}, T_{12} and T_{13} but produced significantly higher yield over recommended doses of fertilizers (T_1 to T_8) during both the years, respectively. Addition of a part of 15 or 30% of either N alone or N and P or N,P and K of the recommended dose of fertilizers at the time of residue incorporation recorded significant superiority over T_2 (rice residue incorporation + recommended NPK) with respect to grain yield. Application of 30% additional NPK with incorporation of rice residue (T_{14}) recorded 48.60 and 51.45 per cent more grain yield than that recorded in T_1 (sowing of wheat without incorporation of rice residue and recommended NPK) during both the years, respectively.

Table 4.8: Effect of varying rice residue management practices on test weight (g), Grain yield (q ha^{-1}), Straw yield (q ha^{-1}) and biological yield (q ha^{-1}) of wheat

Treatments	Test weight (g)		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})		Biological yield (q ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	30.27	29.97	35.99	35.63	43.19	43.32	79.19	78.95
T_2	31.48	31.80	38.05	38.43	46.04	45.84	84.09	84.27
T_3	34.31	34.99	43.71	44.58	53.76	54.32	97.47	98.90
T_4	34.71	34.88	44.22	44.44	53.51	54.62	97.73	99.06
T_5	35.11	35.22	44.74	44.87	54.58	55.43	99.31	100.30
T_6	35.92	36.14	45.76	46.04	56.29	57.62	102.05	103.66
T_7	36.73	36.87	46.79	46.98	58.49	58.78	105.28	105.76
T_8	37.13	37.39	47.31	47.64	58.66	59.84	105.97	107.48
T_9	39.55	39.67	50.39	50.54	61.48	62.00	111.87	112.54
T_{10}	40.36	40.40	51.42	51.47	62.22	62.71	113.64	114.18
T_{11}	40.76	40.93	51.93	52.14	63.88	64.15	115.81	116.29
T_{12}	41.17	41.29	52.45	52.61	63.46	63.65	115.91	116.26
T_{13}	41.57	41.65	52.96	53.07	66.20	66.73	119.17	119.80
T_{14}	41.97	42.35	53.48	53.96	66.31	67.31	119.79	121.27
SEm±	1.18	1.30	1.50	1.65	1.84	2.05	3.34	3.70
CD at 5%	3.43	3.78	4.36	4.80	5.36	5.95	9.71	10.75

Figure 4.8: Effect of varying rice residue management practices on test weight (g), Grain yield (q ha^{-1}), Straw yield (q ha^{-1}) and biological yield (q ha^{-1}) of wheat



4.3.2 Straw yield:

The data pertaining to straw yield have been presented in Table 4.8 and depicted in Fig. 4.8. The data regarding straw yield presented in Table 4.8 reveal that rice residue incorporation (T_2) produced more straw than residue removed (T_1) though, the differences were significant when a part of 15 or 30% of the recommended dose of fertilizer as an additional dose particularly N was applied at the time of residue incorporation. Maximum straw yield (66.31 and 67.31 q ha^{-1}) was obtained with application of 30% additional NPK at incorporation of rice residue (T_{14}) being at par with T_9, T_{10}, T_{11}, T_{12} and T_{13} but produced significantly higher yield over recommended doses of fertilizers treatments (T_1 to T_8) during both the years, respectively. Addition of 15 or 30% part of either N alone or N and P or N,P and K of the recommended fertilizers at the time of residue incorporation recorded significant superiority over T_2. Application of 30% additional NPK with incorporation of rice residue (T_{14}) recorded 53.53 and 55.38 per cent more grain yield than that recorded in T_1 (sowing of wheat without incorporation of rice residue and recommended NPK) during both the years, respectively.

4.3.3 Biological yield:

The data regarding biological yield presented in Table 4.8 reveal that application of 30% additional NPK with incorporation of rice residue (T_{14}) produced significantly higher biological yield over recommended doses. All the treatment combinations of recommended NPK and additional NPK (T_3 to T_{14}) in those a part or additional N or N

and P or N, P and K were applied at the time of residue incorporation was produced significantly higher biological yield than those recorded under both control plots (T_1 and T_2) during both the years. Application of 30% additional NPK with incorporation of rice residue (T_{14}) recorded 51.27 and 53.60 per cent more biological yield than that recorded in T_1 (sowing of wheat without incorporation of rice residue and recommended NPK) during both the years, respectively.

4.4 Chemical analysis of plant:

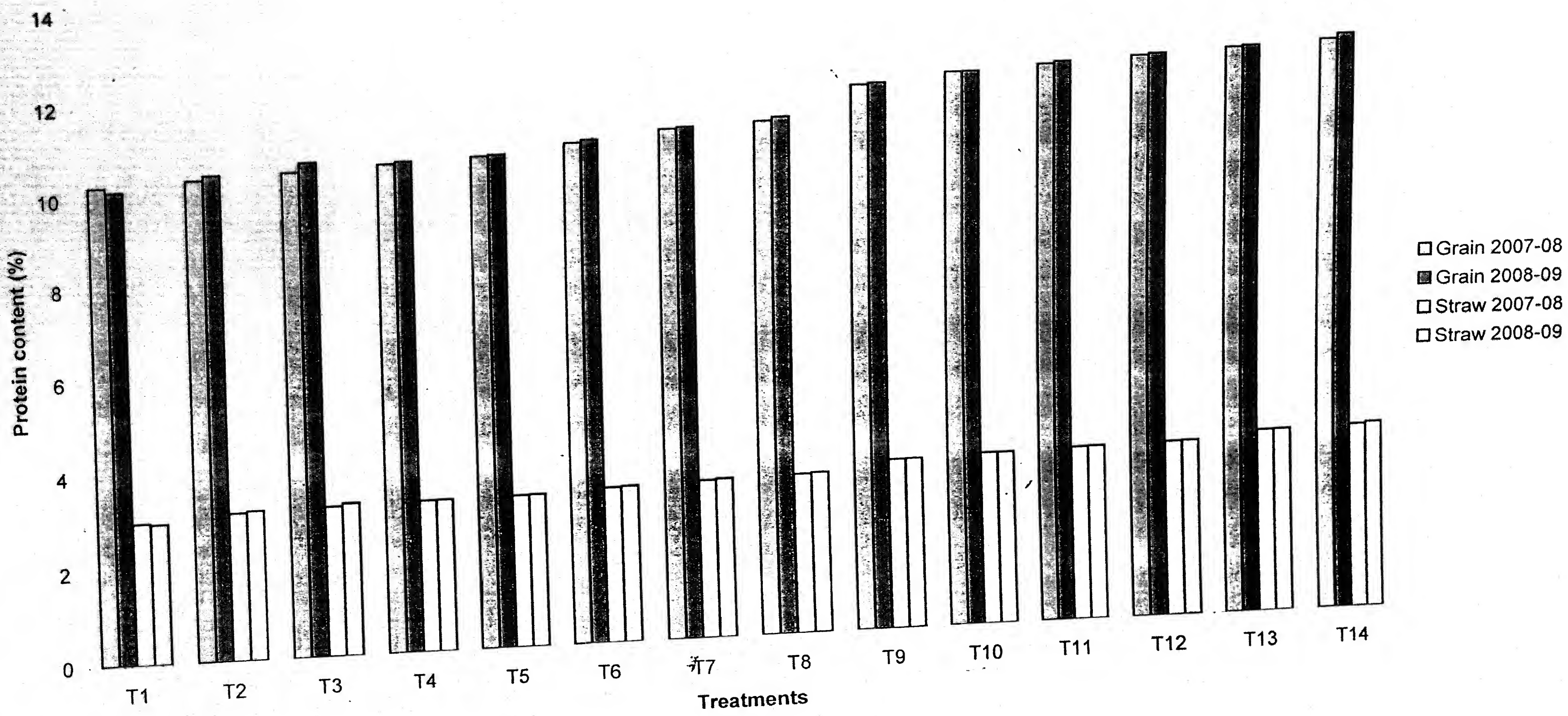
4.4.1 Protein content in grain:

The data pertaining to protein content in grain as influenced by various treatments presented in Table 4.9 and depicted in Fig. 4.9 reveal that the rice residue and nutrient management practices affect the protein content in grain significantly during both the years. However, rice residue incorporation recorded higher value of protein content than sowing of wheat without incorporation of rice residue and recommended NPK (control). In general, the protein content was more in second season than first season. Analogous to grain yield, protein content also increased significantly with each level of over and above recommended doses of nutrient which being at par with each other within the group and these were significantly more over within recommended doses. Application of 30% additional NPK with incorporation of rice residue (T_{14}) exhibiting an increase of 20.19 and 19.25 as well as 21.71, 19.17 per cent in first year and second year

Table 4.9: Effect of varying rice residue management practices on protein content in grain and straw of wheat

Treatments	Protein content (%)			
	Grain		Straw	
	2007-08	2008-09	2007-08	2008-09
T_1	10.28	10.17	3.00	2.97
T_2	10.40	10.50	3.15	3.18
T_3	10.52	10.73	3.19	3.25
T_4	10.65	10.70	3.23	3.24
T_5	10.77	10.80	3.26	3.27
T_6	11.02	11.08	3.34	3.36
T_7	11.27	11.31	3.41	3.43
T_8	11.39	11.47	3.45	3.47
T_9	12.13	12.17	3.68	3.69
T_{10}	12.38	12.39	3.75	3.75
T_{11}	12.50	12.55	3.79	3.80
T_{12}	12.63	12.67	3.83	3.84
T_{13}	12.75	12.78	4.01	4.02
T_{14}	12.88	12.99	4.05	4.09
SEm$\pm$	0.36	0.40	0.11	0.12
CD at 5%	1.06	1.16	0.32	0.36

Figure 4.9: Effect of varying rice residue management practices on protein content in grain and straw of wheat



over control (sowing of wheat without incorporation of rice residue and recommended NPK and rice residue incorporation + recommended NPK at wheat sowing), respectively.

4.4.2 Protein content in straw:

The data pertaining to protein content in straw as influenced by various treatments presented in Table 4.9 and depicted in Fig. 4.9 reveal that the rice residue and nutrient management practices affect the protein content significantly during both the years. However, rice residue incorporation recorded higher value of protein content in straw than sowing of wheat without incorporation of rice residue and recommended NPK (control). Protein content in straw increased significantly with each level of over and above recommended doses of nutrient which being at par with each other within the group and these were significantly more over within recommended doses. Application of 30% additional N+P+K + recommended NPK with incorporation of rice residue (T_{14}) exhibiting an increase of 25.93 and 22.22 as well as 27.38, 22.25 per cent in first year and second year over controls (sowing of wheat without incorporation of rice residue and recommended NPK and rice residue incorporation + recommended NPK at wheat sowing), respectively.

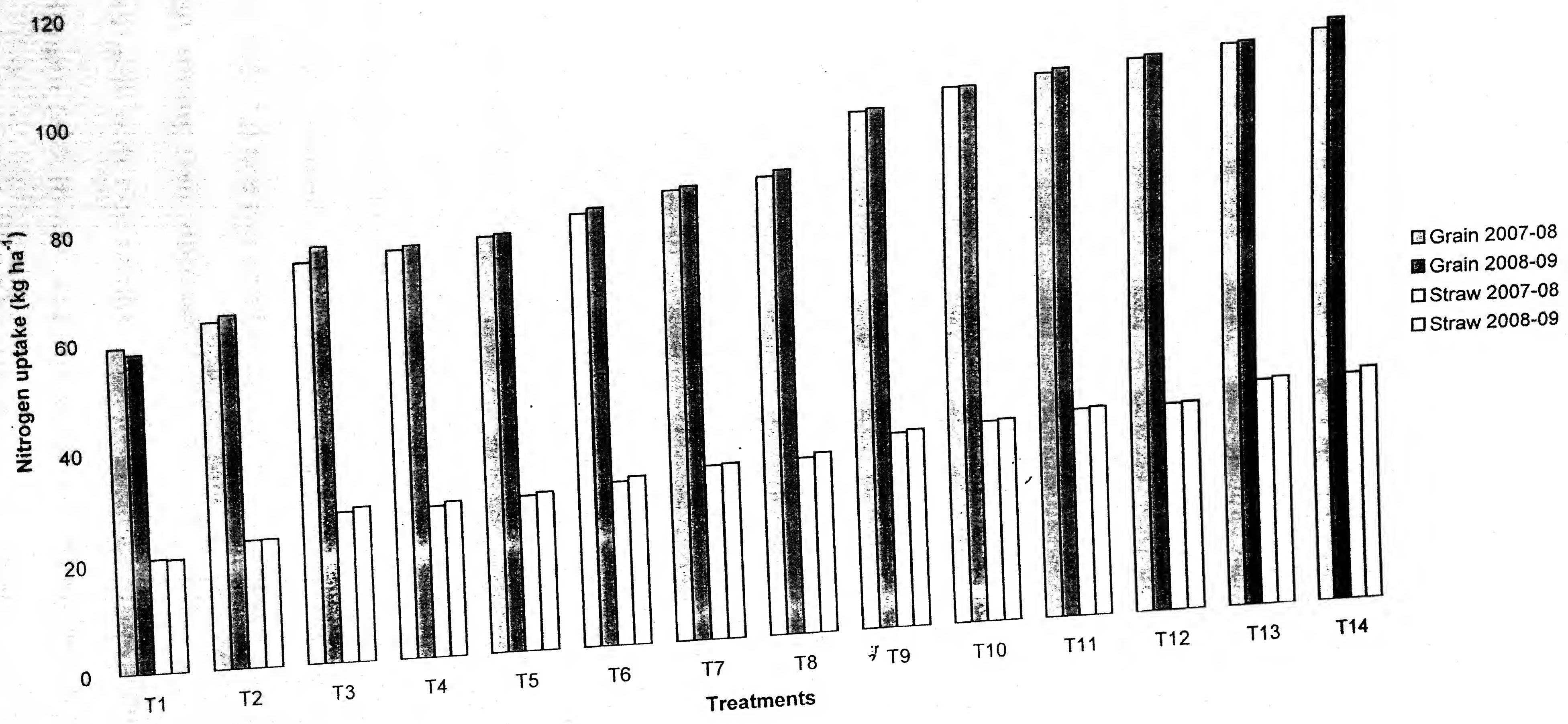
4.4.3 Nitrogen uptake by grain:

The data on nitrogen uptake by wheat have been presented in Table 4.10 and graphically illustrated in Fig. 4.10.

Table 4.10: Effect of varying rice residue management practices on nitrogen uptake in grain and straw of wheat

Treatments	Nitrogen uptake (kg ha^{-1})			
	Grain		Straw	
	2007-08	2008-09	2007-08	2008-09
T_1	59.18	58.00	20.73	20.59
T_2	63.31	64.58	23.20	23.33
T_3	73.59	76.56	27.42	28.26
T_4	75.33	76.09	27.61	28.32
T_5	77.09	77.56	28.49	29.02
T_6	80.68	81.65	30.06	30.95
T_7	84.34	85.02	31.94	32.22
T_8	86.21	87.42	32.38	33.26
T_9	97.82	98.41	36.15	36.57
T_{10}	101.85	102.06	37.33	37.66
T_{11}	103.90	104.73	38.71	39.03
T_{12}	105.97	106.60	38.84	39.07
T_{13}	108.06	108.49	42.50	42.93
T_{14}	110.16	112.16	42.97	44.01
SEm$\pm$	2.82	3.17	1.06	1.21
CD at 5%	8.20	9.23	3.07	3.52

Figure 4.10: Effect of varying rice residue management practices on nitrogen uptake in grain and straw of wheat



The nitrogen uptake by grain was significantly higher in rice residue incorporation and nutrient management practices against the control [sowing of wheat without incorporation of rice residue and recommended NPK (T_1) and rice residue incorporation + recommended NPK at wheat sowing (T_2)]. Application of 30% additional N+P+K + recommended NPK with rice residue incorporation recorded highest uptake of nitrogen (110.16 and 112.16 kg ha^{-1}) by grain which was significantly superior over all within recommended doses but found statistically at par with over and above recommended doses of nutrient during both the years of study. Application of 30% additional N+P+K + recommended NPK with rice residue incorporation recorded an increase of 46.28 and 42.53 as well as 48.29 and 42.42 per cent in 2007-08 and 2008-09 in nitrogen uptake by those of recorded under sowing of wheat without incorporation of rice residue and recommended NPK (T_1) and rice residue incorporation + recommended NPK at wheat sowing (T_2), respectively.

4.4.4 Nitrogen uptake by straw:

The nitrogen uptake by straw was significantly higher in rice residue incorporation and nutrient management practices against the control [sowing of wheat without incorporation of rice residue and recommended NPK (T_1) and rice residue incorporation + recommended NPK at wheat sowing (T_2)]. Application of 30% additional N+P+K + recommended NPK with rice residue incorporation recorded highest uptake of nitrogen (110.16 and 112.16 kg ha^{-1}) by straw which was significantly superior over all within recommended doses but found

statistically at par with over and above recommended doses of nutrient during both the years of study. Application of 30% additional N+P+K + recommended NPK with rice residue incorporation recorded an increase of 51.76 and 46.01 as well as 53.22 and 46.99 per cent in 2007-08 and 2008-09 in nitrogen uptake by those of recorded under sowing of wheat without incorporation of rice residue and recommended NPK (T_1) and rice residue incorporation + recommended NPK at wheat sowing (T_2), respectively.

4.5 Post harvest physico-chemical properties of soil:

The data pertaining to physico-chemical properties i.e. bulk density, organic carbon and available nitrogen in soil have been presented in Table 4.11.

4.5.1 Bulk density (BD):

The data presented in Table 4.11 reveal that rice residue incorporation recorded significantly reduced bulk density over sowing of wheat without incorporation of rice residue and recommended NPK (T_1) during both the years. The highest value of bulk density was recorded with sowing of wheat without incorporation of rice residue and recommended NPK (T_1) i.e. 1.54 and 1.56 g cc^{-1} which was significantly higher over those of all residue incorporation and nutrient management treatments during 2007-08 and 2008-09, respectively. All the residue incorporated treatments were found statistically at par with each other in respect of bulk density (g cc^{-1}) during both the years of study.

Table 4.11: Effect of varying rice residue management practices on bulk density, organic carbon and available nitrogen in soil (after harvest)

Treatments	BD (g cc^{-1})		O.C. (%)		Available N (kg ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T_1	1.54	1.56	0.27	0.27	105.80	104.74
T_2	1.33	1.34	0.32	0.32	111.84	112.96
T_3	1.34	1.37	0.32	0.33	128.47	131.04
T_4	1.33	1.34	0.32	0.33	129.98	130.63
T_5	1.31	1.31	0.33	0.33	131.49	131.89
T_6	1.32	1.33	0.33	0.33	134.51	135.32
T_7	1.32	1.33	0.33	0.33	137.54	138.09
T_8	1.33	1.34	0.33	0.33	139.05	140.02
T_9	1.34	1.34	0.34	0.34	148.12	148.56
T_{10}	1.34	1.34	0.35	0.35	151.14	151.29
T_{11}	1.35	1.36	0.35	0.35	152.65	153.26
T_{12}	1.35	1.35	0.35	0.35	154.16	154.63
T_{13}	1.35	1.35	0.36	0.36	155.67	155.99
T_{14}	1.35	1.36	0.36	0.36	157.19	158.60
SEm$\pm$	0.03	0.03	0.01	0.01	4.40	4.85
CD at 5%	0.09	0.08	0.03	0.03	12.80	14.11

4.5.2 Organic carbon (O.C.):

The data presented in Table 4.11 related to organic carbon indicate that rice residue and nutrient management practices affected significantly during both the years.

Incorporation of rice residue recorded significantly higher organic carbon content during both the years. Rice residue incorporation with 30% additional N+P+K + recommended NPK recorded with highest organic content which was statistically at par with all over and above recommended doses of nutrient and rice residue incorporation but found significantly superior over sowing of wheat without incorporation of rice residue and recommended NPK (T_1) and rice residue incorporation + recommended NPK at wheat sowing (T_2) and other within recommended doses.

4.5.3 Available nitrogen:

The data related to available nitrogen (kg ha^{-1}) estimated after harvest of wheat, presented in Table 4.11 and depicted in Fig. 4.11 reveal that rice residue and nutrient management practices causes significant variation in available nitrogen content in soil during both the years. Application of 30 % additional N+P+K + recommended NPK with residue incorporation recorded highest value of available nitrogen, which was at par with other over and above recommended doses and these were significantly superior over control (sowing of wheat without incorporation of rice residue and recommended NPK and rice residue incorporation + recommended NPK at wheat sowing) during first and second years. The values of available nitrogen under

application of 30 % additional N+P+K + recommended NPK with residue incorporation exhibited an increase of 32.69 and 28.85 per cent over control (T_1) and 33.96 and 28.78 per cent over control (T_2) during first and second years, respectively.

4.6 Economics:

The economics (Table 4.12 and Appendix I) of different treatments was worked out on the basis of input analysis. Various components of economics are being described as under:

4.6.1 Cost of cultivation:

The data pertaining to cost of cultivation worked out under different treatments revealed that increase in nutrient level had added more towards rice residue management. ~~As such~~ The highest cost of cultivation of Rs. 17245.41 ha^{-1} was recorded under the treatment of rice residue incorporated with application of 30% additional N+P+K + recommended NPK followed by Rs. 17099.06 ha^{-1} in rice residue incorporated with application of 30% additional N+P + recommended NPK. The lowest ~~cost of~~ cost of cultivation of Rs. 16164.42 ha^{-1} was recorded under sowing of wheat without incorporation of rice residue and recommended NPK (T_1).

4.6.2 Gross income:

Data on gross income computed under different treatments showed that the highest gross income was recorded with rice residue incorporated with application of 30% additional N+P+K + recommended NPK of Rs. 52340.89 ha^{-1} followed by Rs. 51709.89 ha^{-1} in

Table 4.12: Economics of different treatments (Average of 2007-08 and 2008-09)

Treatments	Total cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Net return per rupee investment
T_1	16164.42	34767.57	18603.15	1.15
T_2	16318.12	37098.97	20780.85	1.27
T_3	16318.12	42926.44	26608.32	1.63
T_4	16318.12	43088.37	26770.25	1.64
T_5	16318.12	43582.49	27264.37	1.67
T_6	16318.12	44711.40	28393.28	1.74
T_7	16318.12	45716.43	29398.31	1.80
T_8	16318.12	46276.17	29958.05	1.84
T_9	16529.72	49071.00	32541.28	1.97
T_{10}	16741.31	49975.26	33233.95	1.99
T_{11}	16708.59	50633.81	33925.22	2.03
T_{12}	17099.06	51003.79	33904.73	1.98
T_{13}	16781.76	51709.89	34928.13	2.08
T_{14}	17245.41	52340.89	35095.48	2.04

All figures of this table should be presented in full figures as value of figures is higher. e.g. 34767.57 → 34767

rice residue incorporated with application of 15% additional N+P+K + recommended NPK and the lowest with sowing of wheat without incorporation of rice residue and recommended NPK (T_1) Rs. 34767.57 ha^{-1}.

4.6.3 Net income:

The highest net income of Rs. 35095.48 ha^{-1} was recorded under rice residue incorporated with application of 30% additional N+P+K + recommended NPK followed by Rs. 34928.13 ha^{-1} in rice residue incorporated with application of 15% additional N+P+K + recommended NPK and the lowest Rs. 18603.15 ha^{-1} under sowing of wheat without incorporation of rice residue and recommended NPK (T_1).

4.6.4 Net return per rupee invested:

The highest net return per rupee investment of Rs. 2.08 ha^{-1} per rupee invested was recorded under rice residue incorporated with application of 15% additional N+P+K + recommended NPK followed by rice residue incorporated with application of 30% additional N+P+K + recommended NPK and net return per rupee investment values of Rs. 2.04. The lowest Rs. 1.15 ha^{-1} per rupee invested under sowing of wheat without incorporation of rice residue and recommended NPK (T_1).

Chapter five

DISCUSSION

Chapter-V

DISCUSSION

The results of the experiment entitled "**Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice - wheat sequence**" as presented in the preceding chapter are being discussed, elucidated and interpreted in the light of established principles of agronomy and findings of research workers in the country and abroad.

5.1 Weather conditions during crop growth:

The meteorological conditions prevailed during the crop growth period play an important role on growth and yield of the crop. The performance of wheat in respect to its growth and development and grain and straw yield was better during 2008-09 than that of 2007-08.

Still, the observed

~~The~~ variations ~~were also observed~~ in the growth, yield attributes and

were largely due to the treatment effects.

yield ~~due to variation in weather conditions~~.

5.2 Effect on crop growth:

Nitrogen is the 'key element' amongst essential nutrients plays pivotal role in growth as well as development of the plant by virtue of being an integral part of chlorophyll, proteins the building blocks of the plant body, nucleic acid, purines, pyrimidines and various enzymes. A deficiency of nitrogen leads to stunted growth, irrational development, premature senescence and more specially the chlorosis;

while excess nitrogen causes delayed maturity, retards root growth, enhances the succulence of foliage and water loss through plants (Singh, 1987).

Various rice residue and nutrient management systems did not differ significantly in the initial plant population during both the years (Table 4.1). This is due to the fact that germination totally depends on soil temperature, soil moisture and varietal characteristics, which remained similar at all the treatments. It is obvious because soil moisture in the seeding zone was not a limiting factor for germination of the seeds as the crop was sown after pre-sowing irrigation. Similar, results were also reported by Mishra (1988), who reported that increasing dose of nitrogen did not increase the initial plant population in wheat and Tamak *et al.* (1993) reported that the soil incorporation of rice stubble or straw + stubble had no significant effect on seedling emergence.

The rice residue and nutrient management practices brought about significant variation in growth characters of wheat namely, plant height, number of tillers per running metre, dry matter accumulation, number of leaves per plant, days taken to 75 per cent heading and maturity in both the seasons.

Various rice residue and nutrient management systems significantly affect the plant height with the age of wheat crop (Table 4.2). Rice residue incorporation with 30% additional N+P+K + recommended NPK produced significantly taller plants over sowing of wheat without incorporation of rice residue and recommended NPK

and rice residue incorporation + recommended NPK at wheat sowing during both the years. The increased plant height might be due to cumulative effect of narrow C:N ratio, nutrients availability, soil health and good plant establishment with rice residue incorporation and additional dose of NPK treatment and thus, with the effect of these factors, increased plant height was recorded. Stubble treatment had the little effect on plant height as reported by Griffin *et al.* (1982). Meelu *et al.* (1994) also reported that incorporation of residue had beneficial effects on plant height. Under Hissar conditions, Dhiman *et al.* (2000) reported the adverse effect of residue incorporation on plant height during initial years however; the deleterious effect was counter balanced during the subsequent years. Significant variation in plant height might be also due higher levels of nitrogen resulted in more nitrogen uptake, which caused better metabolization of synthesized carbohydrates into amino acids and protein which in turn stimulated the cell division and cell elongation and thus allowed the plant to grow faster, which expressed morphologically an increase in plant height. Singh (1991) also reported that nitrogen application upto 120 kg ha^{-1} increased the plant height of wheat. Auti *et al.* (1999) reported that plant height was increased with 120:60:60 kg NPK ha^{-1} under clay soil. Increasing level of nitrogen upto 120 and 80 kg ha^{-1} produced taller plant over 0 and 40 kg ha^{-1} under rainfed condition in silty clay loam soil (Kataria *et al.*, 1999).

Rice residue and nutrient management practices significantly affect the number of green leaves per plant (Table 4.3). Rice residue

incorporation with 30% additional N+P+K + recommended NPK produced significantly more number of green leaves per plant over sowing of wheat without incorporation of rice residue and recommended NPK and rice residue incorporation + recommended NPK at wheat sowing during both the years. The increased number of green leaves per plant might be due to cumulative effect of narrow C:N ratio, nutrients availability, soil health and good plant establishment with rice residue incorporation and additional dose of NPK treatment and thus, with the effect of these factors, increased number of green leaves was recorded. Stubble treatment had the little effect on number of green leaves as reported by Griffin *et al.* (1982). Meelu *et al.* (1994) also reported that incorporation of residue had beneficial effects on LAI. Significant variation in number of green leaves per plant might be due higher levels of nutrient resulted in more plant height, nitrogen uptake, which caused better metabolization of synthesized carbohydrates into amino acids and protein which in turn stimulated the cell division and cell elongation and thus allowed the plant to grow faster, which expressed morphologically an increase in number of leaves per plant. Auti *et al.* (1999) reported that number of leaves was increased with 120:60:60 kg NPK ha^{-1} under clay soil.

Substantial variations also occurred in dry matter production due to different rice residue and nutrient management systems during both the years (Table 4.4). Rice residue incorporation coupled with 30% additional N+P+K + recommended NPK produced significantly more dry matter as compared to sowing of wheat without

incorporation of rice residue and recommended NPK as well as rice residue incorporation + recommended NPK at wheat sowing during both the years at all the growth stages. The increased dry matter accumulation might be due to higher growth and development, number of tillers, plant height and leaf area index. Maximum soil LAI is not measured during experimentation organic matter content with rice residue incorporation helped not only in better development and spread of crown root but also in greater and synchronized tillering. The results are in conformity to those of Bhat *et al.* (1991) they ~~was~~ reported that ~~the~~ dry matter yield of maize increased with crop residue incorporation under Ludhiana condition. Similar findings were also reported by Hegde (1998).

Number of tillers per running metre was affected significantly due to various rice residue and nutrient management systems at all the stages of the crop growth during both the years (Table 4.5). It increased progressively upto 90th day stage and thereafter decreased. Significantly higher number of tillers per running metre was obtained with rice residue incorporated as compared to rice residue removed during both the years. This might be due to good LAI and root growth Not measured and development in the upper layer of soil surface where these got the good opportunity for nutrient uptake. This made possible with rice residue incorporation due to higher organic matter content in soil. Good pulverization of soil may be achieved as field was ploughed for residue incorporation. It increased the availability of nutrients, which resulted into increased tillering and thus, number of tillers per running metre. However, at initial stage these activities were very slow

and had a very little effect on number of tillers under various systems. In relation to these findings, Meelu *et al.* (1994) also reported the higher number of tillers with incorporation of residue treatment in the soil.

The higher number of tillers associated with increasing levels of nutrient might be due to less tiller mortality, enhanced photosynthetic area, proper nourishment, enhanced cell expansion and various metabolic processes in presence of abundant supply of nutrients which resulted into increased tillering and, thus, more number of shoots per running metre. These findings are in support to those of Malik (1981) who noted positive effect of nitrogen upto 240 kg ha^{-1} on the number of tillers in wheat. Patel *et al.* (1991) also reported the increase in number of shoot with increasing levels of nitrogen. Roy *et al.* (1991) from Dinazpur (Bangladesh) reported that nitrogen application from 0 to 120 kg N ha^{-1} increased the number of tillers substantially. Maximum numbers of shoots were found with 120 kg N ha^{-1} has also been reported by Singh (1991) from Ludhiana.

Rice residue and nutrient management practices influenced the development stages significantly during both the years (Table 4.6). Increasing doses of NPK delayed 75 per cent heading and maturity. Rice residue incorporation coupled with 30% additional N+P+K + recommended NPK took significantly more number of days for 75 per cent heading and maturity as compared to sowing of wheat without incorporation of rice residue and recommended NPK. The ~~plausible~~ possible reasons for ~~the fact~~ this may be that additional nutrient application delays

the senescence of leaves as a result of activation of IAA which remain active in photosynthesis and ultimately increased the production of photosynthates for relatively longer period which turn, might have delayed the heading as well as maturity. Patra (1990) and Kishor (1998) also reported the delayed flowering and maturity with higher dose of nitrogen. Similar, findings have also been reported by Kataria *et al.* (1999). They observed that heading and maturity were delayed by 4 days with increasing N levels from 40 to 80 kg ha^{-1}.

5.3 Effect on yield attributes:

All the yield attributes influenced significantly due to various rice residue and nutrient management practices during both the years. Values of various yield-contributing characters were highest when rice residue incorporated coupled with additional dose of NPK as compared to other control during both the years (Table 4.7 & 4.8). Number of effective tillers per running metre, length of spike, number of spikelets spike^{-1}, number of sterile spikelets per spike and test weight were recorded significantly higher with rice residue incorporation and application of 30 % additional N+P+K + recommended NPK treatments over sowing of wheat without incorporation of rice residue + recommended NPK and rice residue incorporation + recommended NPK during both the years. This might be due to the fact that addition of crop residue improved the soil health, thus, increased effective tillers, length of spike, grains spike^{-1} and other yield contributing characters. After the decomposition of crop residue, nutrients released ~~to soil~~ slowly through out the growth

period. Positive effects on yield contributing characters were also reported by Sharma and Mitra (1989). They reported that straw incorporation with starter dose of 20 kg N ha^{-1} gave higher values of yield attributes. Increased in 1000-grain weight due to incorporation of rice straw was also reported by Azam *et al.* (1991). Similar, findings were also reported by Singh *et al.* (1998), Dwivedi and Thakur (2000) and Das *et al.* (2001) in rice under north-east Indian conditions.

An increase in yield attributes is also the function of nitrogen. Application of additional nutrient resulted in higher tissue differentiation and produced greater number of florets, which in turn developed to more number of spikelets. Patel *et al.* (1995) reported that increasing level of nitrogen upto 150 kg ha^{-1} increased the effective tillers m^{-1} row length, length of spike, spikelets spike^{-1}, grains spike^{-1}, grain weight spike^{-1} and test weight. Similar, findings were also reported by Auti *et al.* (1999) in clay soil and Dwivedi and Thakur (2000) in silt clay loam with recommended dose of fertilizer 120:60:60 kg N, P_2O_5 and K_2O ha^{-1}, respectively. Similar, results were also reported by Das *et al.* (2001) under sandy loam conditions with 100% recommended dose of NPK.

5.4 Effect on yields:

Yield is the resultant of coordinated interplay of growth and yield contributing characters. Additional fertilization pushed up the removal of nutrient and water from soil by the crop, which might have enhanced the photosynthesis and translocation of assimilate from source (leaves and stem) to sink vis-à-vis grain yield. Grain and straw

yields affected significantly due to rice residue and nutrient management practices during both the years (Table 4.8). The higher grain and straw yields were recorded when rice residue incorporation was coupled with application of 30% additional N+P+K + recommended NPK which was significantly more than other treatments during both the years. It might be due to the addition of crop residue and additional fertilization which might have improved the soil health and consequently higher uptake of available nutrients from the soil. Thus, increased the effective tillers running m^{-1}, spike length, number of spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1} and 1000-grain weight (Table 4.8), which ultimately attributed to increase in grain yield. Crop residue on decomposition released nutrients slowly through out the growth period, which resulted better plant growth and higher straw yield. Incorporation of wheat straw and burning both had higher grain and straw yield of rice over the straw removed (Maskina *et al.*, 1987). ~~Under the~~ gn clay loam soil, incorporation of rice straw ~~increased the~~ produced higher wheat yield over sandy loam soil as reported by Singh *et al.* (1992). Increase in grain and straw yields of wheat with residue incorporation were also reported by Dwivedi and Thakur (2000), Das *et al.* (2001), Gangwar *et al.* (2005), Singh *et al.* (2006), and Bakht *et al.* (2009).

measured m^{-2}

5.5 Effect on chemical properties of plant:

Protein content in grain was greatly influenced due to rice residue and nutrient management practices during both the years (Table 4.9). Protein content in grain and straw were ~~increased~~ higher with

application of 30% additional N+P+K + recommended NPK being at par with 15% additional N+P+K + recommended NPK, showing its significant superiority over sowing of wheat without incorporation of rice residue + recommended NPK and rice residue incorporation + recommended NPK. Application of additional NPK increased the protein content was mainly due to increase in nitrogen content and its uptake (Table 4.10), which constitute about 16 per cent of protein. It may be stated that due to higher availability of nitrogen in the plants, the synthesized carbohydrates were converted more rapidly in to protein. Application of nitrogen @ 150 kg ha^{-1} increased the protein content ~~were~~ was reported by Singh and Singh (1975) and Patel *et al.* (1995). Dwivedi and Thakur (2000) reported that application of 120 kg N ha^{-1} increased the protein content under silt clay loam soil condition. Verma (2001) also reported that under sandy loam soil condition protein content increased upto 150 kg N ha^{-1}. Increase in protein content with incorporation of rice residue over no residue under silt loam condition has also reported by Dwivedi and Thakur (2000).

duplicate pl combine it

Nitrogen uptake by grain and straw influenced significantly by rice residue and nutrient management practices during both the years (Table 4.10). Highest nitrogen uptake by grain and straw was recorded under the treatment when rice residue incorporated with 30% additional N+P+K + recommended NPK against sowing of wheat without incorporation of rice residue + recommended NPK and rice residue incorporation + recommended NPK. Increase in nitrogen

uptake by grain and straw may be due to better root establishment which resulted in better translocation of absorb nutrients from soil and its translocation to plant and seed which may cause higher plant growth, grain and straw yields and ultimately increased the uptake of nitrogen. Adequate supply of nutrients in the root zone increased the movement of nutrients in soil solution and ultimately their greater absorption and utilization by the growing plants. Kumar *et al.* (1995) reported that each increment of nitrogen level from 60 to 180 kg ha^{-1} increased the grain and straw yields as well as N uptake under loamy soil condition at Karnal. Kumar *et al.* (2000) also reported that nitrogen uptake increased with increasing level of nitrogen upto 120 kg ha^{-1} under sandy loam soils of Bihar. Increased nitrogen uptake in residue incorporated treatment was mainly due to cumulative effect of better soil health, increased the availability of nutrients and better root and plant growth and development, which enhanced the crop yield. These results are in conformity to those reported by Dwivedi and Thakur (2000) under silt-clay loam soil ~~that~~ wherein incorporation of rice straw increased the nitrogen uptake. Similar, findings were also reported by Das *et al.* (2001) in rice.

5.6 Effect on physico-chemical properties of soil:

The bulk density of soil was recorded before sowing and after harvest of wheat (Table 4.11). Rice residue and nutrient management treatments altered the bulk density during both the years. The higher values were recorded with sowing wheat without incorporation of rice residue + recommended NPK. Lower values of bulk density were

recorded with rice residue incorporation + recommended NPK due to addition of crop residue through incorporation and its subsequent decomposition added organic matter in soil and thus mass per unit volume of soil reduced. It is also due to incorporation of rice residue in the soil, which contained higher organic matter content in rice straw. Walia *et al.* (1995) reported that incorporation of crop residue decreased the bulk density (0-15 cm). Incorporation of wheat straw or rice straw decreased the bulk density under sandy loam soil has been reported by Das *et al.* (2001). Application of additional nutrient with incorporation of rice residue also increases the bulk density up to some extent this might be due to the fact that additional dose of nitrogenous fertilizers accelerate the rate of mineralization through narrowing the C/N ratio. Sharma *et al.* (2009) found that the crop residue retention on the soil surface has multifarious benefits. It conserves soil moisture, moderates temperature, suppresses weeds, improves soil physicochemical properties and helps to make the system sustainable.

Organic carbon content in soil was recorded before and after harvest of wheat (Table 4.11). Rice residue and nutrient management significantly influenced the organic carbon content during both the years. Significantly higher organic carbon content was recorded with rice residue incorporation with application of 30% additional N+P+K + recommended NPK and rice residue incorporation with application of 15% additional N+P+K + recommended NPK against sowing of wheat

without incorporation of rice residue + recommended NPK. It is probably due to the fact that addition of carbonaceous substances in soil which on decomposition added organic matter. Verma and Bhagat (1992) have also recorded the maximum soil build-up of organic carbon under the rice straw chopped and incorporated with animal manure, followed by animal manure and straw mulch, while minimum organic carbon under rice straw burnt and rice straw removed. Lonjewar *et al.* (1992) also reported that addition of plant biomass increased the organic matter in soil. Incorporation of wheat or rice straw increased the organic matter of soil has also been reported by Das *et al.* (2001). Singh *et al.* (2006) also reported that retention of rice straw caused a small increase in the soil organic carbon levels in the surface 0-75 mm layer due to rapid carbon turn over rates.

Available nitrogen in soil was recorded before and after harvest of wheat (Table 4.11). Rice residue and nutrient management treatments differ significantly the available nitrogen during both the years. Maximum available nitrogen was recorded with application of 30% additional N+P+K + recommended NPK followed by rice residue incorporation with application of 15% additional N+P+K + recommended NPK against sowing of wheat without incorporation of rice residue + recommended NPK. Significant differences were recorded due to application of additional nutrient through fertilizers, after the direct application it enhanced the availability of nitrogen.

Increased in available nitrogen with wheat straw incorporation was reported by Gangaiah *et al.* (1999). Similar, findings were also reported by Das *et al.* (2001).

5.7 Economics:

It is ~~very~~ clear from the Table 4.12 ~~and Appendix I. The~~ maximum cost of cultivation incurred under the treatment combination rice residue incorporation with 30% additional N+P+K + recommended NPK (T_{14}) where, maximum fertilizer and its application costs with rice residue incorporation were included. The lowest cost of cultivation was recorded in sowing of wheat without incorporation of rice residue + recommended NPK (T1). This might be due to less ~~reduced~~ cost of fertilizer and land preparation ~~which was less~~ under residue ~~removal~~. The highest gross income of Rs. 52340.89 ha^{-1} was recorded under rice residue incorporation with 30% additional N+P+K + recommended NPK (T_{14}). This might be due to fact that higher grain and straw yields were recorded with this treatment. The maximum net return (Rs. 35095.48 ha^{-1}) was recorded under rice residue incorporation with 30% additional N+P+K + recommended NPK (T_{14}). Net return per rupee invested (Rs. 2.08) ~~per rupee invested~~) was recorded under rice residue incorporation with 15 ~~30~~% additional N+P+K + recommended NPK (T13 ~~T14~~). This was possible due to increased grain and straw yield and less cost of fertilizers than T_{14} treatment.

Chapter six

SUMMARY AND CONCLUSIONS

Chapter VI

SUMARRY AND CONCLUSIONS

With a view to study the **"Effect of varying rice residue management practices on growth and yield of wheat and conservation of organic carbon in soils under rice – wheat sequence"**, a field experiment was carried out at Research Farm of Brahmanand Post Graduate College, Rath (Hamirpur) U.P. during rabi season of 2007-08 and 2008-09. The experiment was laid out in a randomized block design having 14 treatments were tested with three replications. The soil of the experimental field was silt loam (Paruwa) in texture with neutral in reaction (pH 7.8 and 7.7) having low organic carbon (0.24 and 0.26%) and available nitrogen (117.37 and 121.15 kg ha^{-1}), medium phosphorus (16.62 and 17.65 kg ha^{-1}) and higher available potash ~~potassium~~ (261.0 and 268.50 kg ha^{-1})

The wheat variety PBW 343 was sown on 18-11-2007 and 20-11-2008 with the common seed rates of 100 kg ha^{-1}. Five irrigations were given coinciding with the critical stages of the crop. The observations were recorded to elucidate the phenomenon operating the yield manifestation. The salient features of the experimental results have been condensed here under.

Initial plant population was not influenced due to rice residue and nutrient management practices at 30th day after sowing during both the years.

Plant height was significantly influenced at all the stages of the crop growth during both the years. The highest plant height was recorded at harvest stage (74.03 and 74.69 cm) under rice residue incorporation with 30% additional N+P+K + recommended NPK during first and second year, respectively.

Numbers of green leaves running metre^{-1} were significantly influenced under various rice residue and nutrient management systems at all the stages of the crop growth, during both the years. The highest number of green leaves running metre^{-1} was recorded (585.64 and 590.92) at 90th day stage under rice residue incorporation with 30% additional N+P+K + recommended NPK during first and second year, respectively.

Dry matter accumulation was affected significantly with various rice residue and nutrient management practices at all the growth stages of crop growth. The highest dry matter running metre^{-1} (194.54 and 196.29 g) was recorded under rice residue incorporation with 30% additional N+P+K + recommended NPK at harvest stage during first year and second year, respectively.

Numbers of tillers were significantly influenced under various rice residue and nutrient management systems at all the stages of the crop growth, during both the years. The highest number of tillers per running metre was recorded (73.13 and 73.79) at 90th day stage under rice residue incorporation with 30% additional N+P+K + recommended NPK during first and second year, respectively.

Days taken to 75 per cent heading and maturity differed significantly due to different rice residue and nutrient management practices during both the years.

Yield attributing characters were influenced due to various rice residue and nutrient management practices during both the years. The highest values of yield attributes viz., number of effective tillers metre^{-2} (323.96 and 326.88 metre^{-2}), spike length (10.42 and 10.51 cm), number of spikelets spike^{-1} (15.92 and 16.07) and 1000-grain weight (41.97 and 42.35 g) was recorded under residue incorporation with 30% additional N+P+K + recommended NPK during both the years.

Grain and straw yield were influenced significantly with various rice residue and nutrient management practices during both the years of experimentation. The highest grain yield of 53.48 and 53.96 q ha^{-1} and straw yield of 66.31 and 67.31 q ha^{-1} were recorded under rice residue incorporation with 30% additional NPK during first and second year, respectively.

Protein content in grain was also influenced significantly due to rice residue and nutrient management practices during both the years. The highest value of protein content was recorded under rice residue incorporation with 30% additional N+P+K + recommended NPK. Protein content in straw was influenced significantly during both the years. Higher protein content was recorded (4.05 and 4.09%) under rice residue incorporation with 30% additional N+P+K +

recommended NPK during first and second year of field experimentation.

Nitrogen uptake by grain and straw was influenced significantly due to rice residue and nutrient management practices during both the years. Significantly higher uptake values of 110.16 and 112.16 kg ha^{-1} in grain and 42.97 and 44.01 kg ha^{-1} in straw were recorded under rice residue incorporation with 30% additional N+P+K + recommended NPK during first and second years, respectively.

Physico-chemical properties were influenced significantly due to rice residue and nutrient management practices during both the years. Significantly decreased bulk density (1.31 and 1.32 g/cc) were recorded with rice residue incorporation with recommended NPK being at par with rice residue incorporation + 30% additional N+P+K + recommended NPK during both the years. However, organic carbon content increased with incorporation of rice residue (0.36 and 0.36%) being at par with rice residue incorporation with 15% additional N+P+K + recommended NPK during both the years. Available nitrogen also differed significantly due to rice residue and nutrient management practices during both the years. The highest values of available nitrogen (157.19 and 158.60) were obtained under rice residue incorporation with 30% additional N+P+K + recommended NPK during 2007-08 and 2008-09, respectively.

CONCLUSION

On the basis of results summarized above, following conclusions may be drawn:

1. Rice stubbles incorporation is the efficient rice residue management practice for the establishment of wheat.
2. Rice residue incorporation with application of additional fertilizers is the suitable method for getting higher yield of wheat.
3. Incorporation of rice residue improved the organic carbon status of the soil.
4. A combination of rice residue incorporation with 30% additional NPK is the most remunerative practice for rice-wheat cropping system.
5. Incorporation of rice stubbles + 30% additional NPK gave maximum net return. But net return per rupee investment was highest with treatment where rice stubbles incorporated with 15% additional NPK + recommended NPK.

Farmers of Bundelkhand region may, therefore, be advised to adopt rice residue incorporation practice with 30% additional fertilizer under rice-wheat cropping system to get higher yield and benefits from wheat.

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APPENDICES

Appendix I: Cost of cultivation (Rs/ha) on the basis of rates prevailed during 2006-07

S.N.	Operation particulars	Cost
A. Cost of cultivation without rice residue incorporation		
(1) Land Preparation		
(i)	One deep ploughing 3 P + 3 L for one day	474.00
(ii)	One pre sowing irrigation 2 L + 20 hrs	516.00
(iii)	Four cross ploughing 4 P + 4 L for two days	1264.00
(iv)	Four planking 1 P + 2 L for 16 hrs	432.00
(2) Sowing		
(i)	Sowing 3 P + 6 L	648.00
(ii)	Seed 100 kg ha^{-1}	2000.00
(iii)	One planking 1 P + 2 for 4 hrs	158.00
(3)	Preparation for irrigation channel 5 L	290.00
(4)	Irrigation charges for three 6 L + 60 hrs	1540.00
(i)	Isoproturon (Arelen 75 W.P.) @ Rs. 265.00 kg^{-1}	265.00
(ii)	2, 4-D Na salt (Knock weed 80% W.P.) @ Rs. 90 kg^{-1}	90.00
(iii)	One spraying 4L for one day	232.00
(5)	Harvesting 20 L for 1 day	1160.00
(6)	Threshing 12 hrs + 6 L	2140.00
(7)	Winnowing bagging 4 L for 1 day	232.00
(8)	Supervision and other costs	500.00
	Total	**11941.00**
(B) Fixed cost		
(9)	Interest on working capital (12% per annum for one year of the period for crop in the field)	716.46
(10)	Rental value of land for 6 month	300.00
	Total cost of cultivation	**12957.46**

Cost of cultivation of rice residue incorporation

S.N.	Operation particulars	Cost
(1) Land preparation		
(i)	Two disc harrowing 5 hrs	750.00
(ii)	One pre-sowing irrigation 2 L + 20 hrs	516.00
(iii)	3 disc harrowing 7.5 hrs	1125.00
(iv)	Four planking 1 P + 2 L for 16 hrs	432.00
(2) Sowing		
(i)	Sowing 3 P + 6 L	648.00
(ii)	Seed Rs. 100 kg ha^{-1}	2000.00
(iii)	One planking 1 P + 2 L for 4 hrs	158.00
(3)	Preparation for irrigation channel 5 L	290.00
(4)	Irrigation charges for three 6 L + 60 hrs	1540.00
(i)	Isoproturon (Arelen 75 W.P.) @ Rs. 265.00 kg^{-1}	265.00
(ii)	2, 4-D Na salt (Knock weed 80% W.P.) @ Rs. 90 kg^{-1}	90.00
(iii)	On spraying 4 L for 1 day	232.00
(5)	Harvesting 20 L for 1 day	1160.00
(6)	Threshing 12 hrs + 6 L	2148.00
(7)	Winnowing bagging 4 L for 1 day	232.00
(8)	Supervision and other costs	500.00
	Total	**12086.00**
(B) Fixed cost		
(9)	Interest on working capital (12% per annum for one year of the period for crop in the field)	725.16
(10)	Rental value of land for 6 month	300.00
	Total cost of cultivation	**13111.16**

Cost of fertilizer application

S.N.	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Rate of N (Rs./kg)	Rate of P (Rs./kg)	Rate of K (Rs./kg)	Total Fertilizer cost (Rs.)	Application charges (Rs.)	Interest	Total (Rs.)
1.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
2.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
3.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
4.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
5.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
6.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
7.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
8.	120	60	60	11.09	18.75	7.67	2916.00	116	174.96	3206.96
9.	138	60	60	11.09	18.75	7.67	3115.62	116	186.94	3418.56
10.	156	60	60	11.09	18.75	7.67	3315.24	116	198.91	3630.15
11.	138	69	60	11.09	18.75	7.67	3284.37	116	197.06	3597.43
12.	156	78	60	11.09	18.75	7.67	3652.74	116	219.16	3987.90
13.	138	69	69	11.09	18.75	7.67	3353.40	116	201.20	3670.60
14.	156	78	78	11.09	18.75	7.67	3790.80	116	227.45	4134.25

Cost of cultivation of various treatments

Treatment combination	Cost of cultivation as per rice residue management	Cost of fertilizer application (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})
T_1	12957.46	3206.96	16164.42
T_2	13111.16	3206.96	16318.12
T_3	13111.16	3206.96	16318.12
T_4	13111.16	3206.96	16318.12
T_5	13111.16	3206.96	16318.12
T_6	13111.16	3206.96	16318.12
T_7	13111.16	3206.96	16318.12
T_8	13111.16	3206.96	16318.12
T_9	13111.16	3418.56	16529.72
T_{10}	13111.16	3630.15	16741.31
T_{11}	13111.16	3597.43	16708.59
T_{12}	13111.16	3987.90	17099.06
T_{13}	13111.16	3670.60	16781.76
T_{14}	13111.16	4134.25	17245.41

Rates of various particulars

S.N.	Particular	Charges (Rs.)
1.	Disc harrowing (per hr)	150.00
2.	Tractorization charges (PZT per/hr)	150.00
3.	Labour charge per day	58.00
4.	One pair bullock per day (q/hrs)	100.00
5.	Cost of seed (Rs./kg)	20.00
6.	Cost of urea (Rs./kg)	5.10
7.	Cost of SSP (Rs./kg)	3.00
8.	Cost of MOP (Rs./kg)	4.60
9.	Cost of irrigation (Rs./hr)	20.00
10.	Threshing charges (Thresher set Rs./hr)	150.00
11.	Isoproturon	265.00
12.	2, 4-D Na salt	90.00
13.	Land Rent per year	600.00
14.	Interest on working capital per annum	12%
15.	Sale price of grain (Rs./q)	850.00
16.	Sale price of straw (Rs./q)	100.00

Economics of different treatments (2007-08)

Treatments	Total cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Net return per rupee investment
T_1	16164.42	34914.18	18749.76	1.16
T_2	16318.12	36947.33	20629.21	1.26
T_3	16318.12	42526.91	26208.79	1.61
T_4	16318.12	42938.79	26620.67	1.63
T_5	16318.12	43482.81	27164.69	1.66
T_6	16318.12	44528.18	28210.06	1.73
T_7	16318.12	45622.40	29304.28	1.80
T_8	16318.12	46076.43	29758.31	1.82
T_9	16529.72	48980.64	32450.92	1.96
T_{10}	16741.31	49928.82	33187.51	1.98
T_{11}	16708.59	50531.98	33823.39	2.02
T_{12}	17099.06	50927.40	33828.34	1.98
T_{13}	16781.76	51638.54	34856.78	2.08
T_{14}	17245.41	52086.40	34840.99	2.02

Economics of different treatments (2008-09)

Treatments	Total cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Net return per rupee investment
T_1	16164.42	34620.95	18456.53	1.14
T_2	16318.12	37250.61	20932.49	1.28
T_3	16318.12	43325.97	27007.85	1.66
T_4	16318.12	43237.96	26919.84	1.65
T_5	16318.12	43682.17	27364.05	1.68
T_6	16318.12	44894.63	28576.51	1.75
T_7	16318.12	45810.46	29492.34	1.81
T_8	16318.12	46475.91	30157.79	1.85
T_9	16529.72	49161.36	32631.64	1.97
T_{10}	16741.31	50021.71	33280.40	1.99
T_{11}	16708.59	50735.65	34027.06	2.04
T_{12}	17099.06	51080.18	33981.12	1.99
T_{13}	16781.76	51781.25	34999.49	2.09
T_{14}	17245.41	52595.38	35349.97	2.05

Appendix II Analysis of variance

Initial plant population per running metre and plant height (cm)

Source of variations	Mean Sum of Square									
	Initial plant population		Plant height (cm) at 30 DAS		Plant height (cm) at 60 DAS		Plant height (cm) at 90 DAS		Plant height (cm) at harvest	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	1.175	2.279	0.349	0.733	2.237	4.692	3.935	8.254	5.630	11.809
Treatment	4.478	4.440	7.089	7.160	45.403	45.858	79.863	80.665	114.257	115.404
Error	3.038	3.609	1.081	1.309	6.925	8.385	12.182	14.750	17.428	21.102

Number of green leaves per running metre

Source of variations	Mean Sum of Square					
	Number of green leaves at 30 DAS		Number of green leaves at 60 DAS		Number of green leaves at 90 DAS	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	13.465	28.242	290.537	2.555	352.357	739.067
Treatment	273.265	276.008	5896.404	5955.591	7151.047	7222.827
Error	41.681	50.470	899.382	2686.455	1090.753	1320.742

Dry matter accumulation metere^{-2}

Source of variations	Mean Sum of Square							
	Dry matter accumulation at 30 DAS		Dry matter accumulation at 60 DAS		Dry matter accumulation at 90 DAS		Dry matter accumulation at harvest	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	0.282	0.002	7.144	14.984	0.229	64.837	158.566	76.336
Treatment	5.730	5.787	144.977	146.432	627.347	633.644	789.096	797.016
Error	0.874	2.611	22.113	26.776	283.311	115.866	125.439	260.893

Number of tillers per running metre

Source of variations	Mean Sum of Square							
	Number of tillers at 30 DAS		Number of tillers at 60 DAS		Number of tillers at 90 DAS		Number of tillers at harvest	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	0.988	2.072	4.436	9.299	5.317	11.146	4.044	8.478
Treatment	31.216	31.704	140.085	142.278	167.909	170.537	127.721	129.720
Error	3.122	3.792	14.012	17.017	16.795	20.396	12.775	15.515

Days taken to 75% heading and maturity

Source of variations	Mean Sum of Square			
	Days taken to 75% heading		Days taken to maturity	
	2007-08	2008-09	2007-08	2008-09
Replication	9.887	19.235	24.329	47.335
Treatment	33.391	34.255	82.170	84.297
Error	26.760	31.596	65.852	77.752

Yield attributing characters

Source of variations	Mean Sum of Square							
	Number of effective tillers $metre^{-1}$		Length of ear head (cm)		Number of spikelets $spike^{-1}$		Number of sterile spikelets $spike^{-1}$	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	104.332	218.714	0.108	0.226	0.257	0.540	0.010	0.017
Treatment	3294.831	3346.393	3.409	3.463	6.222	6.302	0.112	0.114
Error	329.556	400.234	0.341	0.414	0.802	0.972	0.018	0.021

Test weight (g), grain, straw and biological yield (q ha^{-1})

Source of variations	Mean Sum of Square							
	Test weight (g)		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})		Biological yield (q ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	1.789	3.750	2.843	5.960	4.428	9.423	14.366	30.370
Treatment	43.243	43.794	89.780	91.185	148.915	154.291	468.860	481.107
Error	5.574	6.757	8.980	10.906	13.575	16.778	44.635	54.736

Protein content (%) and Nitrogen uptake (kg ha^{-1}) in grain and straw of wheat

Source of variations	Mean Sum of Square							
	Protein content in grain (%)		Protein content in straw (%)		Nitrogen uptake in grain (kg ha^{-1})		Nitrogen uptake in straw (kg ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	0.175	0.365	0.016	0.034	7.141	17.491	1.000	2.596
Treatment	2.795	2.797	0.343	0.346	866.230	879.520	143.372	147.526
Error	0.531	0.642	0.049	0.060	31.806	40.305	4.473	5.850

Bulk density (g cc^{-1}), organic carbon (g) and available N (kg ha^{-1})

Source of variations	Mean Sum of Square					
	BD (g cc^{-1})		OC (%)		Available N (kg ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Replication	0.001	0.001	0.0002	0.0003	24.562	51.490
Treatment	0.009	0.011	0.0015	0.0016	775.668	787.807
Error	0.004	0.003	0.0004	0.0005	77.584	94.223